

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION II

-----X
In the Matter of

FORD INTERNATIONAL SERVICES, INC.
Ringwood Mines/Landfill Site
(Ringwood, New Jersey)

Proceeding Under §3013 of the
Resource Conservation and
Recovery Act (42 U.S.C. §6934)
-----X

ADMINISTRATIVE ORDER
(ON CONSENT)

Index No. II-3013-40102

JURISDICTION

This Administrative Order on Consent ("ORDER") is issued to Ford International Services, Inc. ("Respondent") pursuant to the authority vested in the Administrator of the United States Environmental Protection Agency ("EPA") under Section 3013 of the Resource Conservation and Recovery Act ("RCRA") as amended, 42 U.S.C. §6934. This authority has been delegated to the Regional Administrator, EPA Region II.

FINDINGS OF FACT AND CONCLUSIONS OF LAW

1. Respondent (formerly known as Ford International Studies, Inc. and Ringwood Realty Corp.) acquired certain properties (hereinafter "the site") in the Ringwood, New Jersey area from Pittsburgh Pacific Company on January 7, 1965. Respondent owned said properties until it transferred title to the properties in several transactions as set forth below:

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<u>Deed Date</u>	<u>Acreage</u>	<u>Grantee</u>
11/21/69	87.310	High Point Homes, Inc.
5/14/70	207.97	Public Service Electric and Gas Co.
6/7/70	18.584	High Point Homes, Inc.
11/2/70	289.89	Ringwood Solid Waste Management Authority
11/13/70	122.039	High Point Homes, Inc.
12/21/73	109.249	New Jersey Department of Environmental Protection
12/21/73	35.475	The Housing Operation With Training Opportunity, A New Jersey Corporation Not For Profit

On and after December 21, 1973, Respondent was not an owner or operator of any portion of the site.

2. The Ringwood Mines/Landfill site has been used for the disposal of solid waste. The site comprises several waste disposal areas, including: open dumps, landfills, abandoned mine shafts and pits used for the disposal of industrial and municipal wastes.

3. Personnel from the EPA have conducted an investigation of the site which included a review of pertinent background information, a reconnaissance inspection with a field survey, and sample analyses.

4. Groundwater is the major source of drinking water in Ringwood Borough. Potable water is provided through a municipal distribution system that utilizes bedrock wells and an artesian spring and private commercial/residential wells located adjacent to the site.

5. The site is located within the watershed of the Wanaque Reservoir which supplies drinking water to approximately 65,000 people. Some surface water draining the site, after mixing with

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water from other sources, discharges to the Wanaque Reservoir approximately 1 mile south of the site. There are no drinking water intakes from the Reservoir within three miles of the site.

6. Analysis of samples of on-site surface water and water in mine shafts on the site has demonstrated the presence of volatile organics including benzene (up to 19 parts per billion ("ppb")); xylene (up to 150 ppb); chloroethane (up to 150 ppb); and ethylbenzene (up to 95 ppb). These chemicals, if discarded and disposed of, are hazardous wastes within the meaning of §3013 of RCRA.

7. There are no data which suggest that Wanaque Reservoir water or water supplies used by Ringwood Borough have been contaminated by any waste materials from the site. However, on the basis of the information gathered in the course of EPA's investigation, and all other available information, EPA has determined that the presence of hazardous waste at the facility, and in surface waters and water in mineshafts at the site, may present a substantial hazard to human health or the environment within the meaning of §3013 of RCRA. Specifically, off-site migration of the hazardous wastes listed in Paragraph 6, above, may in the future contaminate the potable water supplies described in Paragraphs 4 and 5, above. Ingestion of water contaminated with such hazardous wastes may pose such hazard.

8. EPA and Respondent recognize that the public interest is served by this Order.

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9. Respondent has had an opportunity to confer with EPA and to state any objections Respondent may have had with respect to the contents of this Order.

10. Respondent's consent to the issuance of this Order shall not be construed as an admission of any liability or responsibility for the conditions at the site. Further, Respondent notes that it is not now and has not been for over ten years either an owner or operator of the site, and Respondent believes there is no continuing conduct connecting it to the site. Nevertheless, Respondent will voluntarily undertake the steps described herein without prejudice to its position that neither RCRA nor §3013 of RCRA is applicable to Respondent.

11. Respondent's consent hereto shall not be construed as a waiver of any defenses which it may wish to raise in any action to enforce the terms of this Consent Order, or in any other proceeding. Nothing contained in this document shall constitute an admission by Respondent with respect to any factual or legal matter, except that Respondent admits that the Regional Administrator has the authority to issue this Order and that Respondent was the owner of the properties described in Paragraph 1, above. Respondent agrees that in any action to enforce the terms of this Order it will not contest the authority or jurisdiction of the Regional Administrator to issue this Order, nor the determinations set forth in Paragraph 13, below.

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12. Respondent and EPA each consent to these Findings and to the following Order without trial or adjudication of any issues of fact or law.

DETERMINATION

13. Upon the basis of the foregoing Findings of Fact and Conclusions of Law, the Regional Administrator, EPA Region II, has determined that the presence of hazardous waste at the site may present a substantial hazard to human health or the environment. The Regional Administrator has further determined that Respondent is a person responsible for conducting the actions ordered herein, which the Regional Administrator deems reasonable to ascertain the nature and extent of such hazard.

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ORDER

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14. Within thirty (30) days after written notice of the signing of this Order by EPA, Respondent shall create and contribute \$460,000.00 to the Ringwood Site Trust Fund (the "Trust Fund"). Such payment is not a fine or penalty nor does it constitute a payment in settlement of any actual or potential liability for a fine or penalty.

15. The Trustee shall use the principal of the Trust Fund to pay Woodward-Clyde Consultants of 201 Meadowbrook Boulevard, P. O. Box 290, Wayne, New Jersey 07470 (the "Consultant") to perform the work described in Attachment A (the "Work").

16. The Morgan Guaranty Trust Company of New York shall act as Trustee to administer the Trust Fund pursuant to the terms and the provisions of a trust instrument to be executed within thirty days from the date of the signing of this Order. Respondent shall submit to EPA a copy of such trust instrument within 5 days after its execution.

INVESTIGATION

17. The Work to be performed is described in Attachment A and, in summary, consists of a testing program designed to determine the nature and extent of hazardous waste releases from the site, if any, and contamination of air, soil, surface waters and groundwaters resulting therefrom, if any, and the nature and extent of the hazard, if any, posed by such releases and contamination.

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18. Consultant shall submit for EPA's approval on or before April 15th, 1984, a Phase I interim report which will provide geologic (structural) mappings of the site, a summary and evaluation of the data collected (pursuant to the specifications in Attachment A), and a Phase II work plan for field work at the site.

19. EPA will review the plan and provide comments within 15 days of receipt of the plan. Consultant shall modify the plan as reasonably necessary to address EPA's comments and shall submit the revised version to EPA within 15 days of receipt of EPA's comments. EPA will approve the revised plan within 15 days of receipt thereof if EPA finds it to be responsive to EPA's comments provided pursuant to this Paragraph 19. If EPA does not find the revised plan to be responsive to its comments, the parties shall immediately meet to resolve any remaining differences. Implementation of the revised plan shall commence within 30 days of written approval thereof by EPA.

PERFORMANCE OF THE WORK, BONDING AND INSURANCE

20. Respondent shall guarantee the faithful and complete performance by the Consultant of the Work. Failure by the Consultant to carry out the Work pursuant to the schedule herein shall constitute a violation of this Order (except as provided pursuant to Paragraph 36). Respondent, after receipt of written notice from EPA of any such failure, shall take any additional steps reasonably necessary to ensure that the Work is completed.

21. The Consultant shall be responsible for completion of the Work and the Consultant agrees to assume and does assume any

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and all liability arising out of or relating to its acts or omissions in the performance of the Work or its failure to fully perform or complete the Work.

22. The Consultant shall purchase a performance bond in the amount of \$920,000.00 , which bond shall assure complete performance of all the Work required pursuant to this Order. In the event of a default by the Consultant on its obligations hereunder, the bond shall provide that the Work shall be promptly, satisfactorily and fully completed and in no event shall the bond authorize surety to avoid its obligation to have the work fully completed. The Consultant shall purchase and maintain in force insurance policies which shall fully protect, at a minimum, the United States, the State of New Jersey, and the public against any and all liability arising out of the Work.

COMPLIANCE WITH APPLICABLE LAW

23. All actions performed by Consultant pursuant to this Order shall be in compliance with all applicable laws and regulations. Consultant shall use Quality Control/Quality Assurance, and Chain of Custody methodologies set forth in Sections 10 and 1.3, respectively, of the publication, "Test Methods for Evaluating Solid Waste" (SW-846).

24. EPA will designate one individual to be the On-Site Coordinator. Said person will be EPA's designated representative at the site, and will have the right to move freely about the site at all times when work is being carried out pursuant to this Order.

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All reports, comments, and other correspondence directed to EPA will be made to the EPA On-Site Coordinator. Consultant shall identify a Facility Coordinator. This person will be Consultant's designated representative at the site and shall be responsible for oversight of the implementation of this Order and the activities required herein.

25. EPA and its designated representatives, including but not limited to EPA employees, agents, contractors, and consultants shall have authority to enter and freely move about the facility or site at all reasonable times, including but not limited to any time that Work is being carried out pursuant to this Order, for the purposes of inspecting and/or observing Consultant's progress in implementing the requirements of this Order, or for the purpose of verifying the data submitted to EPA by Consultant concerning such implementation. EPA and its designated representatives will make good faith efforts to insure that their actions do not unreasonably interfere with the performance of the Work, and they will observe reasonable safety precautions. Consultant shall also permit EPA's designated representatives to inspect and copy all sampling and monitoring data pertaining to Work undertaken pursuant to this Order and to obtain representative samples of soil, air, surface water and groundwater for contaminant testing and evaluation.

26. Upon the oral or written request of the EPA On-Site Coordinator, Consultant shall provide EPA or its representatives with split samples of any samples collected in furtherance of Work performed in accordance with this Order. A written request for

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split samples shall follow confirming such oral request. The results of testing of samples made available by Consultant shall be provided to Consultant upon completion of analysis by EPA.

27. Consultant shall submit to EPA monthly reports of Consultant's progress toward implementation of the Work. Such reports shall be due on the fifteenth day of each month, and shall describe the implementation activities which were carried out during the previous calendar month.

28. All documents produced by Consultant and delivered to EPA in the course of implementing this Order shall be available to the public unless identified as confidential by Consultant in conformance with 40 C.F.R. Part 2. Documents so identified shall be treated as confidential only in accordance with the applicable confidentiality regulations but no document so produced and delivered consisting of either sampling and monitoring data or hydrological or geological information shall be considered confidential.

29. All reports submitted to EPA under the terms of this Order shall be sent by certified mail, return receipt requested, to:

Chief, Hazardous Waste Site Branch
Office of Emergency and Remedial Response
U.S. Environmental Protection Agency
Room 402
26 Federal Plaza
New York, New York 10278

Attention: Mr. Ray Basso

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30. The signatories to this Order agree that:

A. Neither the United States Government nor any agency thereof shall be liable for any injuries or damages to persons or property resulting from acts or omissions of Consultant, its officers, directors, employees, agents, successors, or assigns, in carrying out activities pursuant to this Order, nor shall the United States Government or any agency thereof be held out as a party to any contract entered into by Consultant in carrying out activities pursuant to this Order.

B. Neither the United States Government nor any agency thereof shall be liable for any injuries or damages to persons or property resulting from acts or omissions of Respondent, its officers, directors, employees, agents, successors, or assigns, in carrying out activities pursuant to this Order, nor shall the United States Government or any agency thereof be held out as a party to any contract entered into by Respondent in carrying out activities pursuant to this Order.

C. Respondent shall not be liable for any injuries or damages to persons or property resulting from acts or omissions of Consultant, its officers, directors, employees, agents, successors, or assigns, in carrying out activities pursuant to this Order, nor shall Respondent be held out as a party to any contract entered into by Consultant in carrying out activities pursuant to this Order.

31. This Order shall apply to and be binding upon Respondent and Respondent's receivers, trustees, successors, and assigns; and upon Consultant, and Consultant's officers, directors, employees,

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agents, servants, receivers, trustees, successors, and assigns, and upon all persons acting on behalf of Consultant.

32. Nothing contained in this Order shall affect any right, claim, interest or cause of action of any party hereto with respect to third parties.

33. If Consultant fails to adhere to the deadline for submittal of its final report to EPA under this Order, Consultant shall pay a penalty of Five Hundred Dollars (\$500.00) for each day such failure continues. Any such penalty shall accrue as of the date the report is due, and shall be due and payable 10 days following receipt of a written demand by EPA, and shall be due and payable every thirtieth day thereafter. Payment of any such penalty shall be made by certified check payable to the Treasurer, United States of America, with a notation of the docket number of this Order, and mailed to:

Regional Hearing Clerk
U.S. Environmental Protection Agency
Region II
26 Federal Plaza
New York, New York 10278

After making at least one written demand to Consultant for payment of such penalties EPA may, if such demand is not honored within 10 days thereafter, make a written demand to Respondent for payment of such penalties, and Respondent shall pay such penalties within 30 days of receipt of such written demand. Consultant shall reimburse Respondent for any penalties Respondent pays pursuant to this Paragraph 33.

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Consultant agrees that its failure to pay any penalties pursuant to this Paragraph 33, or to reimburse Respondent for any penalties Respondent pays pursuant to this Paragraph 33, shall constitute a violation of this Order for which either EPA or Respondent may seek enforcement of the terms hereof.

34. Notwithstanding Paragraph 33, above, Consultant shall verbally notify EPA's On-Site Coordinator, and Respondent, as soon as possible of any delay caused by circumstances beyond the control of Consultant which occurs in the performance of the Work. In addition, within forty-eight (48) hours of such delay, Consultant shall notify EPA's On-Site Coordinator and Respondent in writing and shall fully describe the nature of the delay, the reasons therefor, the expected duration of the delay, the actions which will be taken by Consultant to mitigate further delay and whether the delay may in the opinion of Consultant cause or contribute to an endangerment to public health, welfare or the environment. If the information called for in the notice required by this paragraph is not provided to EPA in a timely fashion, no extension of time shall be granted pursuant to Paragraph 35, below.

35. Any failure of Consultant to complete properly the Work, which failure results from circumstances beyond the control of Consultant and Respondent, shall not be deemed to be a violation of this Order and shall not result in liability for the stipulated penalties set forth in Paragraph 33. Consultant and Respondent must make all reasonable efforts to minimize any delays caused by such circumstances.

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To the extent any delay is caused by such circumstances beyond the control of Consultant and Respondent, the time for performance hereunder shall be extended by a period of time not longer than that which can reasonably be attributed to such circumstances. Increased costs or expenses associated with the implementation of the activities called for in this Order shall not of itself be considered a circumstance beyond the control of Consultant and Respondent. In the event that there is a dispute as to whether or not any delay results from circumstances beyond the control of Consultant and Respondent, the burden of proof shall lie with Consultant and Respondent.

36. EPA will make every effort to assure that Consultant has access to the site at all times in order to perform the work; to take samples at the site; and to conduct surveys or investigations relating to soil, air, surface water and groundwater contamination at, beneath or near the site.

37. Notwithstanding any other penalty provisions with respect to timely completion as provided in Paragraph 33 of this Order, EPA reserves the right to take appropriate enforcement action, including the right to seek monetary penalties, for any violation of law or this Order. In a civil action pursuant to Section 3013(e) of RCRA, 42 U.S.C. §6934(e), Respondent or Consultant may be subject to a civil penalty of not more than \$5,000.00 per day for its failure or refusal to comply with this Order. Further, EPA reserves the right to take action pursuant to Section 3013(d) of RCRA in the event that Consultant or Respondent violate the terms of this Order. EPA acknowledges that Exhibit A, on the basis of the facts now known to it, is

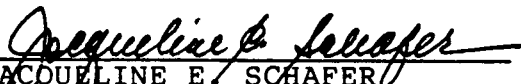
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reasonable to ascertain the nature and extent of the hazard referred to in Paragraph 6 hereof. However, in the event that the investigation program discloses a need for further investigation, EPA also reserves the right to perform any additional studies and take any additional action in response to any release or threatened release of hazardous substances from the site which may be warranted pursuant to RCRA or the Comprehensive Environmental Response, Compensation and Liability Act, 42 U.S.C. §9601 et seq., and to seek recovery of costs incurred in carrying out such studies or such response from Respondent. By consenting to this Order Respondent does not waive its right to contest any such action.

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Dated, entered and effective as of this day of ,
1984, with the agreement and consent of the parties.

U.S. ENVIRONMENTAL PROTECTION AGENCY


JACQUELINE E. SCHAFER
Regional Administrator
U.S. Environmental Protection Agency
Region II

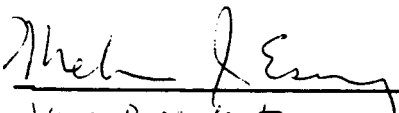
March 16, 1984
Date

FORD INTERNATIONAL SERVICES, INC.


D. R. Jolliffe
Assistant Secretary

MARCH 8, 1984
Date

WOODWARD-CLYDE CONSULTANTS


Vice President

March 13, 1984
Date

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Ringwood

ATTACHMENT A TO
ADMINISTRATIVE ORDER ON CONSENT

RINGWOOD

WORK PLAN + QA FOR R.I.

Judy no. 11-3013-40/02

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Section 1.0

Introduction

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Section 1.0 Introduction

The Ringwood Mines site consists of approximately 870 acres in the Burrough of Ringwood, Passiac County, New Jersey. Several closed iron ore mines are located in the area which has been (and apparently still is) used for disposal of abandoned cars, municipal refuse and disposal of trash and garbage on the surface of the site. In addition, one or more of the mines at the site may have been used for the disposal of various types of refuse at various times in the past.

This Attachment A sets forth the plan of work ("Work") to be accomplished by Woodward-Clyde Consultants (the "Consultants") pursuant to the terms of Administrative Order No. _____ and consists of a preliminary plan of study, a health and safety plan, chain-of-custody procedures, a sampling and analytical plan, a quality assurance control plan and a plan for the collection of certain data, the conducting of a hydrogeological investigation of the site and the conducting of air, soil, surface water and leachate sampling programs, all as set forth below in this Attachment A.

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Section 2.0

Plan of Study

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2.1 INTRODUCTION

The plan of study will consist of a two-phase investigation. The first phase will consist of the collection and evaluation of data as set forth below. The second phase will consist of physical investigation to identify the location and concentration of contamination on land and in the surface and ground water at the site and surrounding area. Each phase will be divided into specific tasks.

2.2 PHASE I - DATA COLLECTION ANALYSIS, AND REPORTING

2.2.1 Task I - Collection and Review of Existing Information

A review and evaluation will be made of the files and aerial photographs that are made available to the consultant by the U.S. EPA Region II; New Jersey Department of Environmental Protection; New Jersey Bureau of Mine Safety; Passaic County Department of Health; Borough of Ringwood; local fire departments; and North Jersey District Water Supply Commission.

Existing information pertaining to the site will be collected, reviewed and evaluated. That information will consist of rainfall records from NOAA; streamflow data from U.S.G.S; Geological and Water Resource Publications of the U.S.G.S and N.J.G.S.; review of water well permit records at the N.J. Bureau of Water Resources within a three-mile radius of the site; and information pertaining to mine configuration and geology available from the N.J. Bureau of Mine Safety; U.S. Department of Defense; and Pittsburgh Pacific Mining Company.

2.2.2 Task 2 - Geologic Evaluation

The geology of the site will be evaluated. This will be done by geologic mapping and by remote sensing. Geologic mapping will be performed to identify and locate rock outcrops around the site. Once the outcrops at the site have been located, representative outcrops will be selected by Woodward-Clyde Consultants; fractures associated with those outcrops identified and mapping of such fractures will be performed. The geometry and characteristics of those fractures will be evaluated statistically.

A lineament study will be performed using commercially available aerial photographs, high altitude photographs (such as U-2 or Skylab), and satellite imagery. The geologic evaluation should provide a preliminary understanding of the geologic structure of the site, and a prediction of the pathways of ground water flow through the bedrock.

2.2.3 Task 3 - Analysis

The information gathered under Task I and Task II will be analyzed. The specific purposes of the analysis will be to: 1) Develop an understanding of the geometry and location of the mine workings; 2) Develop a preliminary understanding of the types and quantities of waste deposited at the site, and its probable locations; and 3) Develop an understanding of the geologic framework of the site.

2.2.4 Task 4 - Recommendations for Phase II Work Plan Studies

Following the completion of Task 3, Woodward-Clyde Consultants will develop a work plan to investigate the location and extent of contamination at the site.

2.2.5 Task 5 - Reporting

The results of the preceeding tasks will be summarized in a report. This report will be called the Interim Report. This report will provide the work plan for undertaking the Phase II studies. This report will be

presented on or before April 15, 1984. The WCC Quality Assurance Program and the Health and Safety Program as provided in Appendix A will be a part of this project.

2.3 PHASE II - GEOLOGICAL AND HYDROGEOLOGICAL INVESTIGATION OF THE SITE AND SURROUNDING AREA

The objectives of Phase II will be to investigate the vertical and horizontal extent of contamination, the type and concentration of pollutants, and to provide the information that would be reasonably necessary for the basis of remedial action. Investigations of this type typically consist of conducting air, soil, surface water, ground water and leachate sampling and testing. The objectives will be addressed in detail in the work plan for conducting the Phase II investigation. That work plan will be contained in the Interim Report. Phase II shall not constitute or be part of this Attachment A until after the Interim Report is submitted and the Phase II plan is agreed to by EPA.

Section 3.0
Health and Safety Plan

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3.1.0 INTRODUCTION

This preliminary assessment will be used as a basis for the site specific Health and Safety Plan which will be written at a later stage of the negotiations which are presently taking place with the client. The major purpose in presenting this initial assessment is to elucidate upon important health and safety questions which may alter the scheduling of work to be performed by Woodward-Clyde Consultants. The actual Health and Safety Plan will establish specific guidelines and requirements to insure safety at the Ringwood site.

Site Description

The Ringwood Mines site consists of approximately 870 acres in the Borough of Ringwood, Passaic County, New Jersey. Several closed iron ore mines are located in the area which has been (and apparently still is) used for disposal of abandoned cars, municipal refuse and disposal of trash and garbage on the surface of the site. In addition, one or more of the mines at the site may have been used for the disposal of various types of refuse at various times in the past.

3.2.0 WORK PLAN

Objectives

The objective of this work is to perform a testing program designed to determine the nature and extent of any hazardous substance released from the site and contamination of air, soil, surface waters, and ground water resulting therefrom.

Description of Field Investigation Activities

- a. Conducting hydrogeological investigation of the site and surrounding area consisting of:
 - o Placement of monitoring wells to determine the vertical and horizontal extent of contamination, if any, and to provide information on aquifer characteristics.
- b. Conducting air, soil, surface water and leachate sampling programs consisting of:
 - o Performing an air quality survey utilizing a portable organic vapor analyzer and absorption tubes to determine organic vapor release.
 - o Performing a soil sampling program consisting of the collecting and chemical analysis of soil samples.
 - o Performing sampling program consisting of sampling of leachate seeps.

3.3.0 HAZARD ASSESSMENT

Overview

The mines and landfill located on this site have been used as a dump for garbage, trash, plant waste and chemicals over the period of at least 20 years. As a result, a wide range of hazardous substances reside in, on, as well as deep beneath the soil. The soil analyses which have been reported to us characterize the wastes as toxic, ignitable, highly volatile, and flammable. Specific chemicals of interest include metals (e.g., cadmium, chromium and lead), solvents (e.g., ethylbenzene, xylene and chloroethane), and paint removers (e.g., benzene and methylene chloride). Additionally, high levels of bacteria and other microorganisms have been found on the site.

3.4.0 HEALTH AND SAFETY DIRECTIVES

Preliminary Health and Safety Directives

- a. An initial air quality assessment will have to be performed before any work is undertaken onsite. This survey will include air pump collection, GCMS analysis (two samples), Draeger tubes, as well as organic vapor analysis using a portable OVA. This preliminary evaluation will take approximately 4 weeks and will cost approximately \$2,500.^{\$10,000} If significant levels of as yet unanticipated toxics are discovered, a follow-up assessment may also be necessary. Time and cost for this later study will depend entirely upon our earlier findings.
- b. The following safety equipment will be used and should be included in the project budget. Each field investigator will need:
 - o hard hat
 - o safety goggles
 - o ear muffs
 - o half mask respirator with cartridges and filter
 - o gloves
 - o Tyvek coveralls
 - o boots.

In addition, the following supplies should be made available:

- o decontamination equipment
- o first air kits
- o supplied-air respirators.

Proper training will be necessary in order to use all of the above supplies, in particular the supplied-air respirators.

Work will not begin if we are unable to properly train field personnel in the proper use of supplied-air safety equipment. Costs for such training are as yet undetermined.

Section 4.0

Chain of Custody Procedures

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SAMPLING - Implementation; Chain of Custody

1.3 Documentation of Chain of Custody

An essential part of any sampling/analytical scheme is ensuring the integrity of the sample from collection to data reporting. This includes the ability to trace the possession and handling of samples from the time of collection through analysis and final disposition. This documentation of the history of the sample is referred to as Chain of Custody.

Chain of custody is necessary if there is any possibility that the analytical data or conclusions based upon analytical data will be used in litigation. In cases where litigation is not involved, many of the chain-of-custody procedures are still useful for routine control of sample flow. The components of chain of custody - sample seals, a field log book, chain-of-custody record, and sample analysis request sheet - and the procedures for their use are described in the following sections.

A sample is considered to be under a person's custody if (1) it is in a person's physical possession, (2) in view of the person after he has taken possession, (3) secured by that person so that no one can tamper with the sample, or (4) secured by that person in an area which is restricted to authorized personnel. A person who has samples under his custody must comply with the procedures described in the following sections.

The material presented here briefly summarizes the major aspects of chain of custody. The reader is referred to NEIC Policies and Procedures, EPA-330/9/78/001-R (as revised 1/82), or other manual as appropriate, for more information.

1.3.1 Sample Labels

Sample labels (Figure 1) are necessary to prevent misidentification of samples. Gummed paper labels or tags are adequate and should include at least the following information:

- Sample number
- Name of collector
- Date and time of collection
- Place of collection

Labels should be affixed to sample containers prior to or at the time of sampling. The labels should be filled out at the time of collection.

1.3.2 Sample Seals

Sample seals are used to detect unauthorized tampering of samples following sample collection up to the time of analysis. Gummed paper seals may be used for this purpose. The paper seal should include, at least, the following information:

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2 / SAMPLING - Chain of Custody

Collector _____ Sample No. _____

Place of Collection _____

Date Sampled _____ Time Sampled _____

Field Information _____

Figure 1. Example of Sample Label

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Sample number (This number must be identical with the number on the sample label)

Collector's name

Date and time of sampling

The seal must be attached in such a way that it is necessary to break it in order to open the sample container. An example of a sample seal is shown in Figure 2. Seals must be affixed to containers before the samples leave the custody of sampling personnel.

1.3.3 Field Log Book

All information pertinent to a field survey or sampling must be recorded in a log book. This should be bound, preferably with consecutively numbered pages that are 21.6 by 27.9 cm (8-1/2 by 11 in.). As a minimum, entries in the log book must include the following:

Purpose of sampling (e.g., surveillance, contract number)

Location of sampling point

Name and address of field contact

Producer of waste and address, if different than location

Type of process (if known) producing waste

Type of waste (e.g., sludge, wastewater)

Suspected waste composition, including concentrations

Number and volume of sample taken

Description of sampling point and sampling methodology

Date and time of collection

Collector's sample identification number(s)

Sample distribution and how transported (e.g., name of laboratory, UPS, Federal Express)

References such as maps or photographs of the sampling site

Field observations

Any field measurements made (e.g., pH, flammability, explosivity)

Signatures of personnel responsible for observations

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4 / SAMPLING - Chain of Custody

NAME AND ADDRESS OF ORGANIZATION COLLECTING SAMPLES

Person Collecting Sample _____ Sample No. _____
(signature)

Date Collected _____ Time Collected _____

Place Collected _____

Figure 2. Example of Official Sample Seal

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Sampling situations vary widely. No general rule can be given as to the extent of information that must be entered in the log book. A good rule, however, is to record sufficient information so that someone can reconstruct the sampling without reliance on the collector's memory.

The log book must be protected and kept in a safe place.

1.3.4 Chain-of-Custody Record

To establish the documentation necessary to trace sample possession from the time of collection, a chain-of-custody record should be filled out and accompany every sample. This record becomes especially important if the sample is to be introduced as evidence in a court litigation. A chain-of-custody record is illustrated in Figure 3.

The record should contain the following minimum information.

Sample number

Signature of collector

Date and time of collection

Place and address of collection

Waste type

Signature of persons involved in the chain of possession

Inclusive dates of possession

1.3.5 Sample Analysis Request Sheet

The sample analysis request sheet (Figure 4) is intended to accompany the sample on delivery to the laboratory. The field portion of this form is completed by the person collecting the sample and should include most of the pertinent information noted in the log book. The laboratory portion of this form is intended to be completed by laboratory personnel and to include at a minimum:

Name of person receiving the sample

Laboratory sample number

Date of sample receipt

Sample allocation

Analyses to be performed

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Figure 3. Example of chain-of-custody record.

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SAMPLING ANALYSIS REQUEST

PART I: Field Section

Collector _____ Date Sampled _____ Time _____ hours

Affiliation of Sampler _____

Address _____
number street city state zip

Telephone () _____ Company Contact _____

LABORATORY
SAMPLE
NUMBERCOLLECTOR'S
SAMPLE NO.TYPE OF
SAMPLE*

FIELD INFORMATION**

_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

Analysis Requested _____

Special Handling and/or Storage _____

PART II: LABORATORY SECTION**

Received by _____ Title _____ Date _____

Analysis Required _____

* Indicate whether sample is soil, sludge, etc.

**Use back of page for additional information relative to sample location.

Figure 4. Example of hazardous waste sample analysis request sheet.

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1.3.6 Sample Delivery to the Laboratory

The sample should be delivered to the laboratory for analysis as soon as practicable - usually within 1 or 2 days after sampling. The sample must be accompanied by the chain-of-custody record (Figure 3) and by a sample analysis request sheet (Figure 4). The sample must be delivered to the person in the laboratory authorized to receive samples (often referred to as the sample custodian).

1.3.7 Shipping of Samples

Any material that is identified in the DOT Hazardous Material Table (49 CFR 172.101) must be transported as prescribed in the table. All other hazardous waste samples must be transported as follows:

1. Collect sample in a 16-ounce or smaller glass or polyethylene container with nonmetallic teflon-lined screw cap. Allow sufficient air space (approximately 10% by volume) so container is not liquid full at 54° C (130° F). If collecting a solid material, the container plus contents should not exceed 1 pound net weight. If sampling for volatile organic analysis, fill VOA container to septum but place the VOA container inside a 16-ounce or smaller container so the required air space may be provided. Large quantities, up to 3.785 liters (1 gallon), may be collected if the sample's flash point is 23° C (75° F) or higher. In this case, the flash point must be marked on the outside container (e.g., carton, cooler), and shipping papers should state that "Flash point is 73° F or higher."
2. Seal sample and place in a 4-mil-thick polyethylene bag, one sample per bag.
3. Place sealed bag inside a metal can with noncombustible, absorbent cushioning material (e.g., vermiculite or earth) to prevent breakage, one bag per can. Pressure-close the can and use clips, tape or other positive means to hold the lid securely.
4. Mark the can with:
Name and address of originator
"Flammable Liquid N.O.S. UN 1993"
(or "Flammable Solid N.O.S. UN 1325")

NOTE: UN numbers are now required in proper shipping names.

5. Place one or more metal cans in a strong outside container such as a picnic cooler or fiberboard box. Preservatives are not used for hazardous waste site samples.

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6. Prepare for shipping:

"Flammable Liquid, N.O.S. UN 1993" or "Flammable Solid, N.O.S. UN 1325"; "Cargo Aircraft Only" (if more than 1 quart net per outside package); "Limited Quantity" or "Ltd. Qty."; "Laboratory Samples"; "Net Weight" or "Net Volume" (of hazardous contents) should be indicated on shipping papers and on outside of outside shipping container. "This Side Up" or "This End Up" should also be on container. Sign shipper certification.

7. Stand by for possible carrier requests to open outside containers for inspection or modify packaging. It is wise to contact carrier before packing to ascertain local packaging requirements and not to leave area before the carrier vehicle (aircraft, truck, etc.) is on its way.

1.3.8 Receipt and Logging of Sample

In the laboratory, a sample custodian should be assigned to receive the samples. Upon receipt of a sample, the custodian should inspect the condition of the sample and the sample seal, reconcile the information on the sample label and seal against that on the chain-of-custody record, assign a laboratory number, log in the sample in the laboratory log book, and store the sample in a secured sample storage room or cabinet until assigned to an analyst for analysis.

The sample custodian should inspect the sample for any leakage from the container. A leaky container containing multiphase sample should not be accepted for analysis. This sample will no longer be a representative sample. If the sample is contained in a plastic bottle and the container walls show that the sample is under pressure or releasing gases, the sample should be treated with caution since it may be explosive or release extremely poisonous gases. The custodian should examine whether the sample seal is intact or broken, since a broken seal may mean sample tampering and would make analysis results inadmissible in court as evidence. Any discrepancies between the information on the sample label and seal and the information that is on the chain-of-custody record and the sample analysis request sheet should be resolved before the sample is assigned for analysis. This effort might require communication with the sample collector. Results of the inspection should be noted on the sample analysis request sheet and on the laboratory sample log book.

Incoming samples usually carry the inspector's or collector's identification numbers. To further identify these samples, the laboratory should assign its own identification numbers, which normally are given consecutively. Each sample should be marked with the assigned laboratory number. This number is correspondingly recorded on a laboratory sample log book along with the information describing the sample. The sample information is copied from the sample analysis request sheet and cross-checked against that on the sample label.

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1.3.9 Assignment of Sample for Analysis

In most cases, the laboratory supervisor assigns the sample for analysis. The supervisor should review the information on the sample analysis request sheet, which now includes inspection notes recorded by the laboratory sample custodian. The technician assigned to analysis should record in the laboratory notebook the identifying information about the sample, the date of receipt, and other pertinent information. This record should also include the subsequent testing data and calculations. The sample may have to be split with other laboratories in order to obtain all the necessary analytical information. In this case, the same type of chain-of-custody procedures must be employed at the other laboratory and while the sample is being transported to the other laboratory.

Once the sample has been received in the laboratory, the supervisor or his assignee is responsible for its care and custody. He should be prepared to testify that the sample was in his possession or secured in the laboratory at all times from the moment it was received from the custodian until the analyses were performed.

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Section 5.0

Sampling and Analytical Plan

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HAZARDOUS WASTE MANAGEMENT PRACTICE

TECHNICAL MEMORANDUM NO. 2 SAMPLE PRESERVATION, PACKAGING, AND SHIPMENT

2.1 Sample Classification, Packaging & Shipment

2.1.1 Purpose

The purpose of this Technical Memorandum is to present procedures by which samples can be classified, preserved, packaged, and shipped to minimize changes in the samples, exposure of contaminated material to the environment, and cross contamination of samples.

2.1.2 General Considerations

Samples should be classified on the basis of the suspected level of contaminant concentration. This classification determines subsequent packaging and labeling requirements, shipping procedures and laboratory handling of samples. Consequently, it is important to make informed judgments about contamination concentration early in the planning stage of an investigation because of the effect this factor has upon field operations. Sample classification enters into the development of the site safety plan and sampling plan.

Sample packaging involves preparation of the sample container for shipment. The procedures and materials used must adequately protect the sample container from accidental breakage and should be sufficient to prevent any spillage that might occur from escaping into the environment. The expected concentration of contaminants prescribes certain specific packaging that must be used.

Sample labels which must be added for proper sample identification are discussed in Technical Memorandum No. 10. The correct labels which must be applied to sample containers and shipping containers to conform with Department of Transportation (DOT) shipping regulations are included in Sections 2.1.4 and 2.1.5.

Samples classified as hazardous can be shipped only by means specified in the DOT regulations. The restrictions that apply to sample shipment are discussed in Section 2.1.6.

A checklist of materials and procedures used for sample preservation, packaging and shipment is given in Figure 2-1.

2.1.3 Sample Classification

Two categories of sample classification are used by the EPA (Environmental Samples and Hazardous Samples); they are based upon the concentration of contaminants. Initially, concentrations of constituents are estimated based on knowledge of contaminant sources and the contaminant transport

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mechanisms and their effect on contaminant concentrations. It is, therefore, necessary to be conservative in the estimate of containment concentration. Note that the sample classification can be downgraded for subsequent samples.

2.1.3.1 Environmental Samples

Environmental samples are those which contain low concentrations of contaminants. "Low concentration" of contaminants is defined as samples expected to contain less than 10 parts per million (ppm) of any one contaminant. Samples collected off site are considered environmental unless information to the contrary exists. On-site samples may be classed as environmental by the Project Engineer or Project Manager.

2.1.3.2 Hazardous Samples

Two categories of hazardous samples are defined:

1. Medium concentration - samples expected to contain greater than 10 ppm and up to 15 percent (150,000 ppm) concentration of any one contaminant.
2. High concentration - samples expected to contain greater than 15 percent of any one contaminant.

Hazardous samples include on-site soil or water samples that may be highly contaminated, sludge or waste pile samples of concentrated wastes, and any sample from a closed drum or container.

2.1.4 Sample Storage

Samples should not be stored on site for extended periods of time and should be protected from environmental extremes. Shipment to the laboratory should be completed as soon as possible and well within any holding time limits specified for particular analyses (refer to Section 2.2) to allow initiation of analyses within the holding time limits.

If temporary storage is necessary, samples should remain in an area that has been designated as the "sample bank" and is secured to maintain sample integrity and chain of custody requirements. Separate containers should be used to store low, medium and high concentration samples. In addition, it is desirable that samples be stored away from work areas.

2.1.5 Packaging of Samples - Environmental Samples

Environmental samples are not considered hazardous under DOT regulations. In addition, the DOT has stated that dilute solutions of chemical preservatives are not subject to Hazardous Materials Regulations as long as

the concentrations do not exceed specified values (see Table 2.1.1). The procedures described below are based on NEIC recommended procedures for shipment of environmental laboratory samples as presented in "Enforcement Considerations for Evaluations of Uncontrolled Hazardous Waste Disposal Sites by Contractors," draft, April 1980, Appendix D.

The procedures meet the DOT requirement for all packages, as specified in 49 CFR 173.24:

"(a) Each package used for shipping hazardous materials... shall be so designed and constructed, and its contents so limited, that under conditions normally incident to transportation --

- (1) There will be no significant release of the hazardous materials to the environment;
- (2) The effectiveness of the packaging will not be substantially reduced; and
- (3) There will be no mixture of gases or vapors in the package which could, through any credible spontaneous increase of heat or pressure, or through an explosion, significantly reduce the effectiveness of the packaging."

The procedures also meet the requirements for shipments by air, as contained in 49 CFR 173.6:

"(a) Each package shall be so designed and constructed, and its contents so limited, that under conditions normally incident to transportation --

- (1) There will be no significant release materials to the environment.
- (2) Inner containers that are breakable (such as earthenware, glass, or brittle plastic) must be packaged to prevent breakage and leakage under conditions normally incident to transportation. These completed packagings must be capable of withstanding a 4-foot drop on solid concrete in the position most likely to cause damage. Cushioning and absorbent materials must not react dangerously with the contents....
- (3) For any packaging with a capacity of 110 gallons or less containing liquids, sufficient outage (ullage) must be provided to prevent liquid contents from completely filling the packaging at 130° F. The primary packaging (which may include composite packaging), for which retention of the liquid is the basic function, must be capable of withstanding, without leakage, an internal absolute pressure of not less than 26 pounds per square inch or no less than

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the sum of the absolute vapor pressure of the contents at 130° F. (55° C.) and the atmospheric pressure at sea level, whichever is greater.

(4) Stoppers, corks, or other such friction-type closures must be held securely, tightly and effectively in place with wire, tape, or other positive means. Each screw-type closure on any inside plastic packaging must be secured to prevent the closure from loosening due to vibration or substantial changes in temperature."

2.1.5.1 Shipping Containers

All sample containers are placed inside a strong outside shipping container. This container must be able to withstand a 4-foot drop on solid concrete in the position most likely to cause damage. A metal or plastic picnic cooler with a hard plastic liner meets this test. The drainage hole at the bottom of the cooler must be taped shut so that if a sample container is broken and leaks or ice water leaks from the bag into which ice was sealed, the contents cannot escape through the drainage hole. The container should be taped shut in order to obtain an adequate seal around the lid to prevent any leakage should the cooler be turned over.

The shipping container must be marked "THIS END UP" with arrows indicating the proper upward position of the container affixed to all four sides.

2.1.5.2 Ice

Ice should be placed into a plastic bag (minimum 2-mil thick) and that bag sealed tightly. Large trash bags are adequate for a 10-pound bag of ice. The amount of ice used will depend on the available space in the cooler but 10 pounds per 20 quarts of cooler volume should be the minimum to assure sufficient cooling.

2.1.5.3 Glass Containers

The lid of the container should be tightened to assure an adequate seal and taped to prevent loosening during transit. The container may be placed into a clear plastic bag which has a minimum thickness of 2-mil (many sandwich and freezer bags are suitable) and this bag taped tightly shut. Clear plastic is recommended so that sample labels can be read through the bag. The sample bottles should be placed into the shipping container and separated in such a way that contact with other bottles is prevented. They should be wrapped and cushioned in an inert packing material such as styrofoam, closed-cell foam packing material, or an absorbent material such as newspaper or vermiculite. The bags containing ice may be placed to provide some cushioning but keep in mind that the ice will melt and its effectiveness as a packing material will be lost.

2.1.5.4 Plastic Containers

Plastic bottles or cubic containers do not require cushioning material to prevent breakage. Plastic containers do not require individual cushioning material but should be packed in such a way that movement is prevented during transport. Caps should be tightly screwed on and taped to prevent loosening during transit. These bottles may also be placed into a 2-mil-thick, clear plastic bag and the bag sealed.

2.1.6 Packaging of Samples - Hazardous Samples

Hazardous samples are classified as ORM-E (Other Regulated Material - Series E) substances by the DOT. They are treated as a flammable liquid or solid and must be packaged accordingly to conform with DOT requirements.

If a sample is known to contain a material identified in the DOT Hazardous Material Table (49 CFR 172.101), packaging and shipment should conform to the specific requirements for that substance.

If the nature of the samples is unknown, the materials should be prepared for shipment in accordance with DOT regulations for packaging and labeling the ORM-E hazard class. These procedures are described below.

2.1.6.1 Unanalyzed Waste, Excluding Closed Container Samples

The following procedures may be applied to unanalyzed waste samples except those which come from closed containers whose contents are presumed to warrant a more careful packaging as described in Section 2.1.6.2. Each sample container, properly labeled with sample information, should be placed into a 4-mil minimum thickness polyethylene bag, one sample per bag, and the bag sealed tightly with tape. This sealed container is placed into a metal can or overpack (such as a 1-gallon paint can) with incombustible, absorbent cushioning material, such as vermiculite or earth. One bag is placed inside each can. The can lid is closed tightly and sealed using tape or other positive means.

Each metal can must bear the following labels and markings:

1. Testing laboratory name and address and a return address.
2. "Flammable Liquid, N.O.S." or "Flammable Solid, N.O.S."

The abbreviation "N.O.S." means "Not Otherwise Specified."

The following labels must be placed next to one another and near the "Flammable Liquid, N.O.S." marking:

1. "Cargo Aircraft Only" and _____
2. "Flammable Liquid" or "Flammable Solid" and "Dangerous When Wet"

More than one can may be placed in a shipping container surrounded with incombustible packaging material for stability. The outside of the shipping container must bear the following markings and labels:

1. All of the labels described above for the sample cans; and
2. "Laboratory Samples," and
3. "This End Up" on the container top with upward pointing arrows on all four sides.

Using the word "flammable" does not convey the certain knowledge that a sample is, in fact, flammable or how flammable, but is intended to prescribe the class of packaging in order to comply with DOT regulations.

2.1.6.2 Unanalyzed Waste from Closed Containers

The Project Manager should make a judgment as to the hazard class of all samples from closed containers based upon available data. The following procedures provide typical worst-case methods for packaging of materials classed by the DOT as "Poison A" (see Table 2.1-2); this type of "reasonable doubt" practice is provided for in the regulation (49 CFR 172.402 h).

Unless reliable data exclude the possibility of the presence of "Poison A" substances (as defined in 49 CFR 173.326), sample containers of unanalyzed waste from tanks or drums (solid, liquid or gas) must be packaged in a DOT Spec. 3A1800 or 3AA1800 metal compressed gas cylinder.

The sample container is first labeled with required sample information. Then, using a string or flexible wire attached to the neck of the sample container, it is lowered into the metal cylinder which has been partially filled with incombustible, absorbent, packaging material. Allow enough cushioning material between the bottom and sides of the sample container and metal cylinder to prevent breakage. After the sample container is completely covered with cushioning material, the string or wire is dropped into the cylinder. The cylinder valve assembly and protector are replaced.

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The following markings must be placed on a tag wired to the cylinder valve protector or a label affixed to the cylinder itself:

1. "Poisonous Liquid, N.O.S." and -
2. Laboratory name and address and return address

The following label must be placed on the cylinder, regardless of the locations of all other markings:

1. "Poisonous Gas," (the "Poisonous Liquid" label is not acceptable here, even if the sample is a liquid).

One or more cylinders may be placed into the same shipping container. The shipping container must bear the following markings:

1. All of the labels described above for the metal cylinders, and
2. "Laboratory Sample" and "Inside Packages Comply with Prescribed Specifications" should be marked on the top of the container.
3. "This Side Up" marking should be placed on the top of the container with upward pointing arrows on all four sides.

2.1.7 Shipment of Samples

2.1.7.1 Environmental Samples

Environmental samples may be shipped by commercial common-carrier bus, by rental vehicle or air-cargo service to the testing laboratory. Generally samples should be received by the laboratory within twenty-four hours after sampling or sooner, if necessary, to allow initiation of analyses within holding times; see Table 2.2-1.

2.1.7.2 Hazardous Samples

Hazardous samples, excluding those from closed containers, may be shipped by common carrier, air-cargo means.

Carrier-provided bills of lading and certification for restricted articles will be completed and signed. Standard industry forms will be used if carrier does not provide them. One form may be used for multiple shipping containers. The following information should be entered on the shipping papers:

1. "Flammable Liquid (or Solid), N.O.S."
2. "Net Weight" by item or "Net Volume" by item.

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3. "Cargo Aircraft Only"

4. "Limited Quantity" _____

5. "Laboratory Samples"

Shipping containers with unanalyzed wastes from drums or tanks should be entered as "Poisonous Liquid, N.O.S." on the first line above.

Unanalyzed samples taken from closed containers may not be transported by commercial air cargo or common carrier aircraft or by rental, non-government aircraft. Federal regulations require shipment by common, public or commercial ground carrier, or government aircraft.

2.2 Sample Preservation Procedures

2.2.1 Purpose

The purpose of these sample preservation procedures is to maintain to the extent possible the character of materials as they were originally sampled while they are stored and shipped and until they are analyzed.

2.2.2 General Considerations

The containers and procedures used for preservation of samples should be selected to satisfy two important requirements:

1. Samples should be prepared in such a way that accurate and valid analyses may be performed. It is critical to avoid using any materials or procedures that might cause contamination, oxidation or other chemical decomposition or reaction of the sample.
2. All sample preservation methods should adequately meet the requirements of chain-of-custody and sample security.

The following sections provide general information regarding appropriate equipment and methods for sample preservation. Often the specific types of containers, their volumes, preservation, sealing and storage techniques are recommended by the testing laboratory, specified in applicable state or federal regulations, or required by governmental agencies involved in the project. Preferred preservation procedures may change as analytical requirements are revised. Consultation with the testing laboratory may be helpful in preparing sample preservation procedures.

2.2.3 General Considerations for Sample Preservation

Regardless of the nature of the sample, absolute stability for all constituents cannot be achieved. At best, preservation techniques can only retard chemical and biological changes. Chemical changes occur in the

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chemical structure of constituents in response to physical conditions. Metal cations may precipitate; ions may change valence states; some constituents may volatilize or dissolve over time. Biological changes may result in valence changes or binding of soluble materials to organic compounds.

As a general rule, it is best to analyze samples as soon as possible after collection in order to minimize the magnitude of changes in the sample.

Preservation is generally limited to pH control, addition of chemicals and refrigeration. These techniques are intended to retard biological action, retard hydrolysis of chemical compounds, keep metals in solution, and reduce volatility of constituents.

Hazardous samples (those which contain medium or high concentrations of contaminants) should not be fixed with any chemical preservative or cooled.

For environmental samples, refrigeration to maintain the sample temperature near 4° C. is the minimum amount of preservation that should be performed. Samples should not be frozen and dry ice should not be used as the cooling agent (due to shipping restrictions). Chemical preservatives may be added to sample bottles in advance, either by the testing laboratory or by field personnel. The recommended preservatives for various constituents are listed in Table 2.2-1.

If it is not possible to ship environmental samples immediately to the testing laboratory, they should be kept refrigerated continuously. Certain constituents may deteriorate within a given time span regardless of preservation. Based on best available data, recommended maximum holding times for many constituents have been determined. These are included in Table 2.2-1.

If, under any circumstances, the proper preservation technique is not used or if the recommended holding time is exceeded, the data as finally reported should indicate the particular variance.

Volumes of sample required for analysis vary widely depending on laboratory capabilities. The volumes presented herein are "safe" (largest volume) numbers.

2.2.4 Types of Containers

Containers in which samples of soil or water are collected should be constructed of materials that remain inert with respect to the suspected contaminants. Glass and linear polyethylene (LPE) containers are recommended. They should have screw-type lids to assure adequate sealing of the bottles; Teflon inserts should be placed inside the lids of glass containers to prevent sample reaction with the metal lid and improve the quality of the seal.

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The volumes of the containers used for sample collection are dependent upon the analytical requirements. For example, very small amounts of water sample are required for volatile organics analysis while extractable organics analysis may require up to one gallon of sample for analysis; see Table 2.2-1.

Sample containers are often supplied by the laboratory which is contracted to perform the analyses. In these cases, sample bottles are washed and sterilized by the laboratory prior to shipment to the field; any chemical preservatives required may also be added in advance. If this procedure has been followed, it is important to clearly label each bottle as to the type of sample it should contain, e.g., metals, TOC, etc. If laboratory prepared bottles are unavailable, the cleaning procedures described in Section 2.2.4 may be consulted.

A summary of container types recommended for particular analyses is included in Table 2.2-1 of this Technical Memorandum.

2.2.5 Cleaning Procedures for Sample Containers

When at all possible, it is preferable to use containers supplied by the EPA or the testing laboratory that have been cleaned prior to shipment to the field. If sample bottles need to be cleaned by field personnel, the following procedures are recommended by the National Enforcement Investigations Center (NEIC). Cleaning of the sample bottles often requires the use of organic solvents and a facility with adequate hood ventilation is required; an oven for drying the bottles is also needed. Following cleaning, any required preservatives should be added to the appropriate bottles before the lids are put in place. Once a bottle has been cleaned, preserved and sealed, it should not be opened until immediately before the sample is collected.

Bottles and septa used for collection of water volatile organics are washed with a detergent solution, rinsed with organics-free water and dried for one hour at 105 degrees Celsius. New sample bottles and liners used for collection of extractable organics are rinsed with an organic solvent such as methylene chloride or acetone and dried by vacuum until no solvent remains. Previously used bottles are washed with detergent, rinsed with organics-free water, dried and then rinsed with organic solvent.

Bottles used for water metals samples are cleaned with dilute nitric acid and washed with distilled or deionized water. Sample bottles used for other water inorganics are washed with distilled or deionized water.

Bottles used for soil or sediment samples are washed with detergent, rinsed with tap water, then rinsed with organics-free water.

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Jars and bottles used for collection of unanalyzed hazardous waste site samples are cleaned by washing with detergent and rinsing with tap water and deionized water followed by a methanol rinse. The jars or bottles are then oven-dried at 300 degrees Celsius for one hour.

2.2.6 Sealing Sample Containers

Under most circumstances sample bottles can be adequately sealed by hand tightening the lid. The lids may be taped to further guard against small leaks. This procedure provides a measure of security. Tampering with the sample would likely involve disturbance of the tape seal.

2.2.7 Preservation Procedures - Environmental Samples

The procedures described below have been reproduced from the publication, "Enforcement Considerations for Evaluations of Uncontrolled Hazardous Waste Disposal Sites by Contractors," U. S. EPA, National Enforcement Investigations Center, April 1980. They are summarized in Table 2.2-1. Volumetric guidelines given are based on required sample size for laboratory analyses. Container sizes referenced are selected to meet sample size requirements.

2.2.7.1 Water Samples

Organics:

Water samples for organics analyses should be collected in glass bottles equipped with Teflon-lined screw caps. Water supply and other samples suspected of also containing residual chlorine should have 0.008 percent $\text{Na}_2\text{S}_2\text{O}_3$ added. These water samples should be preserved by cooling with ice to below 4° C.

Regulatory or other considerations may require that duplicate samples be collected for purgeables (volatile organics). Samples for purgeables should be collected in 40 ml glass vials equipped with Teflon-backed silicon septum screw caps. Samples for extractables should be collected in one-gallon or four one-liter glass bottles with Teflon-lined caps.

Metals:

Water samples for metals analysis should be collected in one-liter high-density polyethylene bottles with solid polyethylene or polyethylene-lined caps. Bakelite caps should be avoided. The bottles are cleaned with dilute nitric acid and washed well with distilled or deionized water. The samples should be preserved with nitric acid to below pH 2. Nitric acid concentration should not exceed 0.15 percent if the sample is to be shipped via air cargo; see Table 2.1-1.

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Ammonia and TOC:

Water samples for ammonia and TOC analyses should be collected in 500 ml polyethylene bottles. The samples should be preserved with sulfuric acid to below pH 2. Sulfuric acid concentration should not exceed 0.35 percent if the sample is to be shipped by air cargo; see Table 2.1-1. The samples are then stored at 4° C.

pH and Fluoride:

Water samples for pH and fluoride analysis should be collected in 500 ml polyethylene bottles and are stored at 4° C. It is desirable to determine sample pH on site if a reliable meter is available.

Cyanide:

Water samples for cyanide analysis should be collected in one-liter bottles and preserved with sodium hydroxide to pH greater than 12. Sodium Hydroxide concentration should not exceed 0.08 percent if the sample is shipped by air cargo; see Table 2.1.1. The samples should be stored at 4° C.

Sulfide:

Water samples for sulfide analysis should be collected in 500 ml polyethylene bottles and 0.04 percent zinc acetate is added.

Phenols:

Water samples for phenols analysis should be collected in one-liter glass bottles and preserved with H_3PO_4 (to a pH less than 4) and 1.0 gm $CuSO_4$ per liter of sample. Samples should be stored at 4° C.

2.2.7.2 Soil or Sediment Samples

Soil or sediment samples should be collected in wide-mouth glass jars equipped with Teflon-lined screw caps. Samples should be preserved by cooling with ice or refrigeration at 4° C. Bottles are cleaned with detergent then rinsed with tap water and organics-free water.

2.2.7.3 Soil, Sediment, or Rock Samples for Physical Testing

Samples of surficial or subsurface materials may be retrieved for testing of their physical or engineering properties. In such instances, the sample containers used do not need to be cleaned to the same extent as is required for chemical analysis samples. The bottle should, however, be washed and free of foreign material. Glass, LPE, or any other suitable container may be used. The volume required depends on the analysis to be performed and

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should be specified by the testing laboratory and presented in the site sampling plan.

Surficial samples can be spooned directly into the sample container. Grab samples and disturbed samples from subsurface sampling may likewise be placed directly into the sample container.

Undisturbed samples can be collected in two ways: (1) sealing the sample tube with the sample inside using plastic caps secured over each end with tape; or (2) extruding the sample in the field and selecting portions for analysis which are then placed into suitable containers. If sealing the sampling tube is desired, consideration should be given to potential contamination of the sample by elements adsorbed from the tube material. Cost and logistics of refrigeration and shipping large tubes should also be considered. Extruding the sample in the field requires additional equipment and increases the possibility of personnel exposure to contaminated samples. The procedure to be followed for samples should be specified in the site-specific sampling plan.

2.2.8 Preservation Procedures - Unanalyzed Hazardous Samples

2.2.8.1 Liquids and Solids, Excluding Samples from Closed Containers

Both liquid and solid samples should be placed in glass jars with Teflon-lined screw cap lids. Eight-ounce wide-mouth round jars of clear glass are recommended. These bottles can be centrifuged to facilitate phase separation in the laboratory prior to analysis. These samples are not treated with chemical preservatives, or cooled.

2.2.8.2 Liquids and Solids from Closed Containers

Samples from closed containers must, unless clear evidence to the contrary is present, be handled as if Poison A is present. Such samples should be placed in 40 ml or similar glass bottles with Teflon-lined caps. The sample container must be small enough to fit through the valve hole of a DOT specification metal cylinder (see Section 2.1.6.2). These samples are not treated with chemical preservatives, or cooled.

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HAZARDOUS WASTE MANAGEMENT PRACTICE

TECHNICAL MEMORANDUM NO. 4 AIR QUALITY MONITORING AND SAMPLING

4.0 Purpose

The purpose of this document is to provide guidance on equipment and methods for identifying air quality conditions that may be detrimental to: (1) the health of personnel engaged in investigations of chemical waste disposal sites and spills, and (2) to the public. Guidance provided in this document supplements that provided in WCC's Health and Safety Manual and is intended for use by individuals with at least a basic knowledge of methods for air quality sampling and analysis.

A wide variety of methods and equipment have been developed for sampling and analyzing air to determine its hazard to health. This document focuses on methods and equipment that either have wide application or are currently used by WCC. As the need arises to use other methods and equipment, this document may be expanded.

During investigations of chemical waste disposal sites or spills, air quality measurements should be performed whenever there is a possibility of encountering health threatening air quality conditions. In most cases, the need to measure air quality will be prompted by suspicion of the presence of airborne chemicals. In some cases, the need will be prompted by the possibility that oxygen deficient conditions exist.

4.1 Measuring Methods and Equipment

4.1.1 Methods

Measuring air quality entails identifying and quantifying chemical substances in air. A variety of methods have been developed to measure air quality. Basically, these methods can be classified as direct and indirect.

Direct methods analyze air without sample pretreatment and provide information almost immediately. They should be used whenever rapid assessments are needed. They are especially useful for determining the presence of hazardous airborne chemicals during field and laboratory operations. These operations include installing observation/sampling wells and other borings, excavations, inspection and sampling of drums and other relatively small containers, confined space entry, opening of sealed sample containers, and laboratory testing of samples. Direct methods are also useful in conducting preliminary on-site air quality surveys.

A variety of electronic instruments and other devices have been developed for direct measurement of air quality. All are designed for the on-the-spot measurements. Some are highly sophisticated; however, compared with instruments used in well-equipped analytical chemistry laboratories, direct measuring instruments and devices are usually less sensitive, have

poorer resolving power, and are limited in the number and kinds of chemicals that they can detect.

Direct measuring equipment is available for both chemical detection without quantification, and for detection, identification and quantification. All are best used for detecting and/or quantifying known chemical substances. Although portable gas chromatographs, infrared spectrophotometers, and other instruments with chemical identifying capabilities can be used for identifying unknown chemicals, use of such instruments in the field for identification purposes is difficult and not generally recommended.

The indirect methods entail collecting air samples for laboratory analysis. They should be used whenever accurate identification and quantification of airborne chemicals are desired. In most cases, the samples do not comprise air per se, but sorbants or filters that remove and concentrate air contaminants upon exposure to air. Because considerable time can be involved in collecting samples and considerable time is always involved in analysis of the samples, indirect methods are best used where immediate knowledge of air quality conditions is not critical.

Indirect methods are recommended for determining air quality at chemical disposal or spill sites prior to commencement of field work, especially where there is a question about the kinds of airborne chemicals present. Samples collected should be analyzed to identify the chemicals they contain and the concentration of each chemical. The method is also recommended for obtaining information on personnel exposure after work commences.

4.1.2 Equipment

4.1.2.1 Direct Measurement

Appendices A and B list many of the instruments available for purchase or rent to perform direct air quality measurements. Information on the kinds of chemicals the instruments are capable of measuring, ranges of detection, principle of operation, and manufacturer are also provided.

Two general kinds of instruments are listed. Dynamic measuring instruments are equipped with pumps that pull air through the detector mechanism. Results are derived from meter readings and/or strip chart recordings. Passive measuring instruments rely on air diffusing into the detector mechanism. Both types of instruments usually require calibration before use. Individuals responsible for operating any of these instruments should read the operating instruction manuals and become thoroughly familiar with the operation of the instruments through training and practice before using them in the field or laboratory.

Organic vapor analyzers (OVA), such as manufactured by Century Systems, Inc., are very useful for detecting and quantifying airborne organic vapors

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and gases. Chemical analysis is via flame ionization. OVA's can be operated in the total vapor mode or in the gas chromatographic mode.

In the total vapor mode, the OVA instrument can be used to determine total concentration of organic compounds in air or the concentrations of specific organic compounds. Concentrations are expressed in parts per million of methane equivalents. When the instrument is used in the total vapor mode to determine the concentration of a specific compound, the instrument should be calibrated with the compound of concern.

In the gas chromatographic mode, OVA's can be used to identify as well as approximately quantify organic vapors and gases. A strip chart recorder is required. For each detectable organic compound in an air sample, a peak is produced on the chart. Identification of the compounds that produced the peaks requires using the instrument to analyze known amounts of each compound suspected of producing the peaks. These reference compounds must be of high purity. Identification of the compounds associated with each peak is accomplished by matching retention times (i.e., time to peak formation) of the reference compounds with those of the peaks produced by the sample. Quantification is achieved by comparing peak heights or areas of matched peaks. Unless one has a fairly good idea of the chemicals present in the samples, identification and quantification can be extremely difficult.

A direct measuring device not listed in Appendices A or B is the colorimetric detector tube. A colorimetric detection tube contains a chemical that changes color when it comes in contact with another chemical. Color development along the length of the tube increases as the concentration of the chemical being measured increases. The concentration of the chemical being measured is determined using a calibration that is provided when the tube is purchased.

Colorimetric detector tube kits are available from several manufacturers. The basic kit comprises a hand-operated pump and an instruction manual. Detector tubes are available as separate items and are selected according to the chemical to be measured. Results can be obtained in a few minutes; however, they may not be reliable if the concentration of the chemical being measured is low. Colorimetric detector tubes are useful in situations where relatively high chemical concentrations are expected and the chemicals have been identified. Appendix C lists detector tubes available from four manufacturers for detecting specific compounds.

4.1.2.2 Indirect Measurements

This section addresses sampling equipment only.

Air samples may be collected by collecting a known volume of air per se or by passing a known volume of air through a suitable sorbent or filter that will remove the chemical substances of interest from the air.

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Samples of air per se are considered grab samples. Such samples may be collected by pumping air into plastic bags of known volume, by drawing air into a gas-tight syringe or evacuated container. Because the volume of air that can be practically collected is relatively small, grab sampling is best used when high air contaminant levels are expected, such as in waste drums and containers.

Sampling by sorption or filtration is performed dynamically (with a pump) or passively (without a pump). The dynamic technique entails drawing air through a sorbing/filtering material at a known rate for a known period of time. The passive technique relies on diffusion. Dynamic sampling has an advantage over grab sampling in that the volume of air that can be sampled is limited only by the sorbing/filtering capacity of the sorbent/filter used. The dynamic sampling technique can be used for areal as well as personnel monitoring.

In dynamic sorption sampling, care must be exercised in choosing a sorbent appropriate to the materials of interest. A wide variety of sorbents are available. Two general purpose solid sorbents are activated carbon and silica gel. Both are relatively effective sorbents for organic vapors and gases and are widely used. Both sorbents can be purchased packed in ready to use tubes or containers. Widely used filter materials include cellulose ester, glass fiber, polyvinyl chloride, and silver membrane. Filters are generally used to sample chemicals in particulate form and chemicals sorbed to particulate matter. Certain filters will sorb nonparticulates.

A variety of hand and electrically operated pumps are available on the market for dynamic sampling. Electrically operated pumps are powered by battery or regular house current, and some are equipped with flow meters and/or timers that automatically shut the pump off at a time set by the operator.

There are a variety of passive samplers with different principles of operation and application. One type, which is used for personnel monitoring is called a personnel monitoring badge, designed to be attached to a person's clothing. The badge comprises a disc coated with finely ground activated carbon enclosed in a plastic protective casing. Organic chemicals in the air are sorbed on the carbon by diffusion. Badges from several manufacturers were recently evaluated by an independent firm. The results indicated that the carbon used in the badges was contaminated with various organic compounds. An unused badge should be included in each group of badges submitted for chemical analysis.

4.2 Procedures

4.2.1 Site Surveys

An air quality survey may be conducted prior to the initiation of activities at the site. Site surveys may employ the use of a

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meteorological station, OVA total vapor concentration scan, oxygen or combustible gas meters, charcoal sorbent tube sampling, and other equipment which may be identified in the site safety or sampling plans. Examples for a checklist of equipment and a checklist of procedures are presented in Figures 4-1 and 4-2, respectively.

The OVA is commonly used to perform a site screening in which total organic vapor concentration of the air is measured during a walk-around of the site. Measurements are recorded on a site map. Enclosed areas might be monitored using combustible gas meters or oxygen meters.

For accurate identification and quantification of airborne chemicals, air samples should be collected using appropriate sample collecting systems at carefully selected locations on a site. Short-term (a few hours) and long-term (8 to 24 hours) sampling times should be considered (see Section 4.2.2).

Air quality surveys may be conducted periodically if the site is substantially disturbed during the field investigation or remedial work; a final air quality survey may be performed following completion of site work to detect any change in ambient air quality resulting from the investigation procedures or remedial work.

4.2.2 Air Sampling

Locations for obtaining air samples should be selected based upon data collected during the site survey; places where elevated OVA readings or combustible gases are detected are logical points for air sampling. In the absence of any detectable concentrations of vapors or gases, samples should be taken in a manner that will adequately cover the areas where potential air quality problems may arise. Locations downwind and adjacent to storage tanks or ponds, lagoons, pits or other waste facilities are prime targets for air quality sampling.

If weather conditions that are likely to affect contaminant volatilization occur (such as heavy rainfall or very hot temperatures), additional air samples may be taken to ascertain the magnitude of their effects on air quality.

Air sampling is accomplished primarily by using charcoal sorbent tubes and sampling pumps; monitor badges are an alternative. The Century OVA equipped with a GC, strip-chart option, may be used to obtain hard copy plots for analysis of compounds. Technical training and experience are required to interpret these graphs accurately; such an effort is likely to be time consuming if more than a few compounds are being sought. Laboratories can often provide turn around times of a few days on sorbent tube samples.

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4.2.3 Occupational Monitoring

4.2.3.1 Identification of Hazardous Conditions

Air samples should be collected or air quality monitoring performed at any site activity that disturbs the environment or brings personnel into proximity with potential contaminant sources (drilling and sampling procedures are examples). The frequency of air monitoring and sampling and the procedures to be used should be specified in the site safety plan.

4.2.3.2 Worker Exposure

Worker exposure is most easily monitored by the use of monitor badges (described in a preceding section); personnel sampling pumps and charcoal sorbent tubes and/or particulate filters may alternately be used. Personnel sampling pumps are equipped with a clip so that the unit can be worn on a worker's belt. An intake tube with a charcoal sorbent tube placed in-line is fastened to the clothing with the intake opening placed near the worker's face. These pumps are capable of operating continuously for about six to eight hours and their batteries may be recharged with the charging unit provided. Sorbent tubes or badges may be submitted for immediate analysis or refrigerated for later analysis. Generally, the quantity of samples collected during personnel monitoring will prohibit analysis of the entire set due to budget restraints. Randomly selected samples may be analyzed as a safety precaution. Badges or tubes worn at times when high OVA readings were detected (or odors reported) should be analyzed to evaluate personnel exposure to potentially high levels of organic vapors. Other samples should be held until the conclusion of the project in case a worker experiences an illness or some other situation prompts the need for analysis of a particular sample.

4.2.4 OVA Monitoring

The Century OVA may be used to obtain direct readings of total organic vapor concentrations. Measurements may be made in the general work area at the potential source of contaminants (such as bore hole openings) and both downwind and upwind of the activity.

Prior to the initiation of drilling, the wind direction and approximate wind speed should be determined at the drilling location. This determination can typically be made by securing lengths of surveyor's plastic ribbon to the drill rig boom or by attaching lengths of surveyor's plastic ribbon to a separate pole. Based on the determination of wind direction, the drill rig should be appropriately located to allow the majority of work to be conducted upwind of the drilling location. In addition, the wind direction indicators should be checked during the drilling process. If the wind direction does change substantially during the drilling process, additional efforts may be necessary to monitor the

concentration of organic vapors in the ambient air in the work space, if work would then be conducted downwind of the drilling location.

The operation of the OVA during drilling is dependent upon the type of drilling being conducted. Different procedures will be utilized for air quality monitoring in the area of the air rotary rig and the auger rigs.

4.2.4.1 Air Rotary Rigs

Recommended procedures for air monitoring in the area of the air rotary drilling rigs are as follows. OVA readings should be obtained from the air discharge of the air rotary rig as the drill bit advances each 10 feet. Caution should be exercised to prevent sampling too close to the discharge area to prevent the lodging of soil particles or water droplets into the entrance port of the OVA. The entrance port may be oriented downwind from the discharge. The OVA may be damaged if particles are allowed to enter into the combustion chamber. In addition, care should be exercised to limit OVA readings in the air discharge due to high concentrations of water vapor in the discharge stream. This excessive moisture may accumulate in the air sample collection tube and in the internal portions of the OVA resulting in freezing during cold weather conditions. If increased organic vapor concentrations are detected in the air discharge stream of the air rotary rig, OVA readings should be obtained for the ambient air of the general working area. OVA readings may be obtained from the open bore hole and/or drill cuttings when the drill rig is shut down or off location. Additionally, the ambient background concentration of organic vapors should be confirmed to ensure that the increased organic vapor concentration is not resulting from work being conducted upwind of the drilling location. OVA readings should also be taken in the ambient air of the work space and at potential source locations if any individual detects the presence of an organic vapor.

4.2.4.2 Auger Rigs

The operation of the OVA in the area of the auger drilling rig is slightly different from the air rotary rig since the auger drilling rig does not produce large volumes of air during the drilling process. It is anticipated that organic vapors which arise from the drilling process will result from volatilization of organic compounds contained in the auger cuttings or from an open bore hole when drilling is completed. For this reason, OVA readings should be obtained in the cuttings spoil area at least once for every 20 feet of drilling. To determine whether auger cuttings are producing substantial organic vapor concentrations, auger cuttings may be collected and sealed in a plastic bag or box to allow volatile organics to accumulate in the entrapped air. An OVA reading can then be taken from this entrapped air in the plastic bag or cardboard box containing the auger cuttings. Additional OVA readings should also be taken in the ambient air as described in the Air Monitoring Procedures for the Air Rotary Drilling Rigs if an organic vapor source is detected in the bore hole, auger

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cuttings, or identified by field personnel. Concentrations thus obtained will be higher than those present in the ambient air. A dilution factor of 100 is generally applicable to such readings, e.g., if auger cuttings in the sealed box produce a reading of 400 parts per million (ppm), the ambient air concentration of vapors produced by these cuttings may be in the order of 4 ppm.

4.2.4.3 Data Interpretation

Depending upon the types of compounds detected during the site survey sampling, upper limits of vapor concentrations for worker exposure may be established. If a compound is present that has been assigned a NIOSH Threshold Limit Value (TLV - the maximum concentration to which a worker can be continuously exposed over an eight-hour workday), that concentration may be used as the limit of exposure above which respiratory protection is mandated. In the absence of a TLV, a provisional maximum exposure limit concentration must be chosen. The limit should be based on available data on the toxicity of the compound in question and chosen by an individual qualified to interpret the toxicological data. In either case, the maximum exposure value is measured at ambient conditions in the work area.

If the predetermined maximum allowable ambient level for organic vapors is exceeded, all work should be stopped and the immediate area evacuated. If the ambient concentrations do not fall immediately, the site safety officer should be notified and provisions of the site safety plan enacted.

The OVA operator must use caution while monitoring the air quality because of the necessity to closely approach potential sources of contamination; levels near the source may be higher than ambient. Proper interpretation of the results of OVA monitoring is essential. Wind direction, effect of exhaust from nearby vehicles or drilling rigs and changes in upwind ambient conditions all must be considered when making air quality judgments. Also, an elevated reading at the bore hole opening or from auger cuttings does not necessarily imply that the ambient air quality has deteriorated to the point at which additional safety precautions must be taken. Continued monitoring of ambient air quality is of prime importance.

A detailed log should be maintained for the use of the OVA at each drilling location. This air monitoring log should include the name of the operator, date, time of reading, depth of boring, wind direction and approximate speed, general climatic conditions, all OVA readings, detections of odors by personnel, and a summary of any other pertinent information. This OVA log will serve as the documentation of air quality during the drilling process and should be maintained in as complete a form as possible.

Other types of meters may also be used if oxygen levels or the presence of combustible gases are of concern, primarily for sampling in closed areas.

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LIST OF REFERENCES

Information and procedures described in this memorandum have been compiled from procedures used at various hazardous waste sites and from consultation with personnel in Woodward-Clyde Consultants Environmental Systems Division, San Francisco.

Linch, A. L., Evaluation of Ambient Air Quality by Personnel Monitoring, Volume 1, Gases and Vapors, Second Edition, CRC Press, Boca Raton, 363 pp., 1981.

NIOSH Manual of Analytical Methods, Volume I, Monitoring Methods, Second Edition, USHEW, PHS, CDC, NIOSH, 1977.

Occupational Health Guidelines for Chemical Hazards, Volumes 1 and 2, F. W. Mackison, R. S. Stricoff, and L. J. Partridge, Jr. Eds., DHHS/NIOSH Publication No. 81-123, 1981.

Potly's Industrial Hygiene and Toxicology, Third Edition, Volume I - General Principle (1978), Volume 2A - Toxicology (1981), Volume 2B - Toxicology (1981), Volume 3 - Theory and Rationale of Industrial Hygiene Practice (1979), G. D. Clayton and F. E. Clayton, Ed. John Wiley & Sons, New York.

Air Sampling Instruments for Evaluation of Atmospheric Contaminants, 5th Edition, American Cont. Governmental Industry Hygiene, 1978.

FIGURE 4-1
CHECKLIST OF EQUIPMENT

A. Equipment required for monitoring

1. Meteorological monitoring station (or source of weather data)
Suppliers:

2. OVA
Suppliers:

3. Combustible gas meter
Suppliers:

4. Oxygen meter
Suppliers:

5. CH₄, H₂S or CO meters
Suppliers:

B. Equipment required for air sampling

1. Gas detector tubes/sampling pumps

Compounds:

Suppliers:

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2. OVA
Suppliers:

3. Charcoal sorbent tubes/sampling pumps
Suppliers:

4. Organic vapor badges
Suppliers:

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FIGURE 4-2
CHECKLIST OF PROCEDURES

- A. Procedures initiated prior to sampling/monitoring**
 - 1. Determine the kinds of monitoring and/or sampling required.
 - 2. Arrange for rental or purchase of necessary equipment.
 - 3. Arrange for laboratory to analyze badges and/or sorbent tubes.
- B. Procedures initiated at least one week prior to sampling/monitoring**
 - 1. Conduct training sessions on operation of equipment.
 - 2. Make arrangements for shipment of equipment to the field.
- C. Sampling/monitoring procedures**
 - 1. Conduct a site survey with the OVA to determine ambient air quality.
 - 2. Select stations for air sampling using charcoal sorbent devices.
 - 3. Conduct air sampling and ship samples for analyses.
 - 4. Establish maximum allowable contaminant levels for ambient air.
 - 5. Conduct occupational monitoring with the OVA at the site of drilling or sampling activities.
 - 6. Assign personnel exposure monitoring devices to drill rig personnel.
 - 7. Store personnel monitoring samples properly and establish criteria for selecting samples for analyses.
 - 8. Maintain accurate, complete records of all OVA (or other) monitoring, air sampling and personnel exposure equipment use.

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HAZARDOUS WASTE MANAGEMENT PRACTICE

TECHNICAL MEMORANDUM NO. 5 WATER SAMPLING

5.1 Surface Water Sampling

5.1.1 Purpose

The purpose of this memorandum is to provide procedures which may be used to obtain representative samples of surface water. A checklist for surface water sampling procedures is presented in Figure 5-1.

Samples of surface waters may be obtained from areas on or near a site and submitted to a laboratory for analyses of particular constituents. Results of these analyses may provide an indication of the extent of contaminant migration from the site by surface or subsurface transport mechanisms, the solubility of contaminants in water (and, thus, the importance of surface water transport), and the potential impact of site contaminants on wildlife, human activity and health, and other sensitive areas of the environment. Checklists for water sampling procedures and equipment are presented in Figures 5-1 and 5-2, respectively.

5.1.2 Sampling Criteria and Methods

Samples will be collected from locations which are selected based upon knowledge of site conditions and associated parameters. Parameters which should be examined include geologic conditions such as natural drainage systems, identified environmentally sensitive areas such as wetlands or wildlife habitats, and the proximity of the site to human activities likely to bring people in contact with contaminants. These activities include, but are not limited to, drinking water intakes on rivers or springs, swimming areas, and fishing areas. Areas of standing or running water on site or leaving the site will be sampled near the site as well as at locations some distance from the site.

Sample collection methods are discussed in Sections 5.1.3, 5.1.4 and 5.1.5. In general, sampling techniques are simple and involve the use of plastic or glass containers or scoops for collection of the samples. More complicated tools are available which provide the capability of sampling from specific depths or collecting multiple phase contaminants that may be present in water.

Beakers, jars or dippers may be used to obtain a surface water sample. They can be attached to a rod or pole to extend the reach of the sampler away from the bank or shoreline (this type of sampling device is commonly called a pond sampler). The sample collection container should be constructed of glass, linear polyethylene (LPE), Teflon, or stainless steel.

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If access to the surface area of a lake, pond, or drainage way is possible by boat or overhead structure, samples may be collected at selected surface points and from different depths.

Weighted bottles may be used to collect a water sample at depth. These devices are basically a jar with a cork or plug in the mouth that can be opened after the bottle is lowered on a rope or chain to a desired depth; once the sample fills the jar, the apparatus is raised to the surface.

If a multiple phase contaminant (for example, immiscible organic liquids) or stratified water layers are suspected, a sampler such as the Coliwasa Sampler may be used to obtain composite water samples in the vertical profile. This sampler is a tube with a stopper at the bottom connected through the tube to a locking handle at the top. The stopper is locked into its open position before the sampler is lowered through the water. As the sampler is slowly lowered into the water the layers of contaminants or other fluids encountered will enter the tube. After the sampler reaches bottom (or the desired depth), the stopper is pulled upward and locked into a seal with the bottom of the tube. The sampler is removed from the water and its contents transferred to a sample bottle or multiple bottles if samples of the stratified layers are desired.

Descriptions of the design, construction and use of the weighted bottle and Coliwasa samplers are contained in EPA publication 600/2-80-018, "Samplers and Sampling Procedures for Hazardous Waste Streams," by E. R. deVera, et al, January 1980; this document is presented as an appendix to "Test Methods for Evaluating Solid Waste," EPA publication SW-846, 1980.

Although contaminant concentrations present in many surface water bodies (especially lakes and rivers) may be low, the same safety precautions and sample preservation techniques should be observed as for collecting any other potentially hazardous sample.

5.1.3 Standing Water

Standing Water includes lakes, ponds, and inundated areas (excluding waste disposal facility impoundments).

Depending on the concentration of contaminants in waters leaving a waste site and the importance of surface water transport in contaminant migration, bodies of standing water may receive potentially high levels of contaminants. Because circulation in enclosed basins is usually minimal, contaminant plumes or stratification may result. It is important to obtain samples that are representative of the water body, both areally and vertically.

The water bodies to be sampled may range in size from small, shallow, runoff-filled depressions, up to lakes several hundred acres or more in areal extent. Small bodies of water can typically be sampled from their

banks. Sampling water from larger bodies requires the formulation of a logical, efficient sampling plan that takes into account the factors described under Section 5.1.2 of this Technical Memorandum. In general, samples are desired at points near the influx of contaminants, near areas of human recreation and water supply intake, or in areas designated as wetlands or wildlife habitats by the U. S. Fish and Wildlife Service (see publication FWS/OBS-79/31, December 1979).

The sampling devices most commonly used are pond samplers, dippers (or scoops) and weighted bottles, operated by hand. Access to sampling points may require the use of a boat.

Observations of the water's physical appearance, depth of the sample, location of the sampling point, and the time of sample collection should be recorded.

5.1.4 Running Water

Running Water includes rivers, streams, and drainage ditches. Water in motion has a high capacity to dissipate contaminants, especially volatile organic constituents. The velocity of water flow, volume of flow and distance of the sampling point from the contaminant source greatly influences the characteristics of a sample. Any sample collected from running water is, in effect, only an indicator of conditions present at one point in time and at one particular location.

Natural or man-made drainage ways leaving or running adjacent to a site are prime locations for samples. Larger streams or rivers should also be sampled, particularly where drainages enter into them. Special attention should be given to rivers that supply public drinking water. Samples should be collected both upstream and downstream from the point of potential contaminant discharge.

Access to a sampling point on a river, stream, or ditch is usually possible from the bank. If the river is wide, bridges may be used for access to points across the entire channel. A boat may be required to reach some sampling points. Near-surface samples may be collected using a pond sampler or dipper. A weighted bottle can be used to obtain samples at depth.

If a low flow rate or shallow channel prohibit direct use of a dipper, a stainless steel shovel can be used to dig a small hole into which water can collect. Sufficient time should be allowed for disturbed sediments to settle before the sample is obtained.

When sampling running water, observations about the physical appearance of the water, its depth and rate of flow, the sample point location, and time of sample collection should be recorded.

5.1.5 Open Water

Open water is defined, for the purposes of this memorandum, as any body of water that is areally unconfined by land surface on at least one side and, in effect, represents an open hydrologic system which allows unrestricted interchange of water and chemical constituents. Included in this definition are: (1) oceans and their direct extensions (such as bays), (2) marshes, estuaries or other wetlands directly influenced by oceanic effects (for example, tides), and (3) lakes with surface areas and volumes large enough that they act effectively as an open system, such as Lake Superior.

In general, open systems are not as sensitive to degradation by point source contamination as are confined waters. However, local geologic constraints, human use of water, or existence of critical wildlife habitats may cause these waters to be highly sensitive to pollutants (especially near the contaminant source). Therefore, these water bodies may require more extensive sampling efforts and planning. Consideration should be given to the tidal stage and other similar effects in planning the details of a sampling program in open water. Sampling at the wrong tidal stage is a common error which can produce misleading results.

Methods for obtaining samples from open waters are similar to those described for standing water. Dippers and weighted bottles are the most commonly used equipment for sample collection. Boats typically are required to gain access to offshore sampling locations.

5.2 Ground Water Sampling Procedures

5.2.1 Purpose

The purpose of this section is to provide procedures for obtaining representative samples of ground water. The following general considerations are applicable to sampling ground water. A checklist for ground water sampling procedures is presented in Figure 5-2.

Ground water samples can be collected from monitoring wells installed on or immediately adjacent to the site, from existing wells on site or in the site vicinity, and from seeps or springs located on or near the site. These samples may be analyzed for specified organic, inorganic, and metal constituents. The results of these analyses may assist in assessing the ambient ground water quality upgradient from the facility, quantifying the concentrations of contaminants leaving the facility and entering the ground water system, indicating the extent and direction of contaminant migration off-site, and identifying potential threats to human health and the environment.

Measurements of ground water table elevation in wells may be used to establish the direction and gradient of ground water movement.

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Collection and analyses of samples from nested monitoring wells installed at various depths may provide an indication of vertical differences in ground water quality and whether a vertical hydraulic gradient exists at the site.

Consideration should be given to detection and sampling of insoluble fluid phases of contaminants which may be floating on the water surface or may be encountered along the bottom of the water bearing formation.

The collection of samples on a regular, periodic basis may allow detection of time-dependent variations in contaminant concentration and/or contaminant movement.

Data from ground water analyses are often used to identify the degree of hazard and to design site remedial actions.

5.2.2 Ground Water Elevations

The elevation of the ground water table at each well should be measured prior to each flushing and sampling. An electrical ground water level indicator or appropriate measuring tape may be used to determine the depth of water below ground surface. If high contaminant concentrations are expected, disposable cord coated with a water sensitive color indicator should be used. Following use, the cord may be placed in a plastic bag for disposal. This prevents potential exposure of sampling personnel to contaminants and possible cross contamination of wells due to ineffective decontamination of equipment. A similar approach using sensitive color indicators on tapes may be used to detect levels of insoluble fluids in wells.

5.2.3 Well Flushing and Sampling Methods

To remove stagnant water, stratified fluids, or residual drilling contaminants in or near the filter zone, wells should be flushed prior to sampling. The amount of pumping or bailing which is required from a well before sampling is dependent on many factors. A common procedure is to pump or bail the well until three to five well volumes have been removed. If the well has a slow recharge, it should be pumped or bailed dry. Each well should be allowed to recharge prior to sampling. Samples should be obtained within twenty-four hours after flushing if sufficient recharge exists. If recharge is not rapid enough to provide sufficient volume of water for the complete set of analyses, additional water may be collected as recharge permits. If recharge to the well is sufficiently fast, samples may be obtained immediately after flushing. The time, method of flushing and volume of water removed should be recorded on a sample data sheet. Special care in handling and disposal may be required for certain fluids generated during well flushing.

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Sampling and flushing can be accomplished by a variety of methods. The type of system used is a function of the type and size of well construction, pumping level, type of pollutant, and analyses to be performed. Ideally, sample withdrawal mechanisms should be inert with respect to contaminants, easily decontaminated and reused, and able to operate at remote sites in the absence of external power sources.

Several commonly used methods of sample withdrawal are described in the subsequent paragraphs.

5.2.3.1 Bailers

One of the simplest methods of sampling water wells is the use of bailers. Bailers may be constructed of stainless steel, PVC or Teflon. An easily fabricated bailer consists of a length of PVC pipe capped with a foot valve, which is suspended on a rope and lowered and raised by hand.

The advantages of bailers are:

1. They can be constructed from materials compatible with the parameter of interest.
2. A separate bailer may be dedicated to each well to minimize cross contamination.
3. No external power source is required.
4. Sample collection by a bailer is the most readily available preferred method for collection of volatile organic samples due to reduced sample agitation.

The disadvantages of bailers are:

1. Transfer of water sample from the bailer to the sample bottle may result in aeration of the sample or volatilization of some organics due to agitation.
2. Cross contamination can be a problem if a reusable bailer is not adequately cleaned after each use.
3. They may be difficult or impractical to use in deep wells.

5.2.3.2 Suction Lift Pumps

There are a variety of pumps available that can be used when the water table is within suction lift, i.e., less than about 20 feet below ground surface. Centrifugal pumps are the most commonly available, are highly portable and have pumping rates from 2 to 40 gpm. Most of these require a

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foot-valve on the end of the suction pipe to aid in maintaining a prime. An external power source is required.

Peristaltic pumps are low-volume suction pumps suitable for sampling shallow, small diameter wells. Pumping rates are generally low but can be readily controlled within desirable limits. Peristaltic pumps typically cannot be used for well flushing due to their low flow rates. An external power source is required.

Hand operated diaphragm pumps are available that can be operated at high pumping rates which facilitate rapid flushing of the well and lower pumping rates for subsequent sampling. One major advantage is portability.

The advantages of suction lift pumps are:

1. Generally, suction lift pumps are readily available, relatively portable, and inexpensive.
2. Disposable PVC or Teflon tubing may be attached to pump inlets and lowered into the well to avoid cross contamination of wells.

The disadvantages of suction lift pumps are:

1. Sampling is typically limited to ground water situations where water levels are less than about 20 feet below ground surface.
2. Pumping may result in sample agitation, degassing and loss of volatile compounds.
3. Decontamination of some pumps is required.

5.2.3.3 Portable Submersible Pumps

Ground water investigations may require the collection of samples from depths which exceed the limitations of bailers or suction lift pumps. A submersible pump can be lowered or raised in a monitoring well using a hose line that supports the weight of the pump, conveys the water from the well, and houses the electrical cable. A portable generator can be used to provide electricity for both the pump and its winch assembly. The entire assembly can be mounted in a pickup or van.

The advantages of submersible pumps are:

1. Pumps are portable and can be used to sample several monitoring wells in a brief period of time.
2. Depending on the size of the pump and the pumping depths, relatively large pumping rates are possible.

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The disadvantages of submersible pumps are:

1. Submersible pumps currently available typically require a minimum well casing inside diameter of 3 inches. Small diameter pumps have a limited availability and are expensive.
2. They require the services of a service vehicle - either a van or truck.
3. They may not be suitable for sampling of volatile organics due to sample agitation and possible contamination of well water by pump materials.
4. Adequate decontamination of the pump and entire hose assembly may be difficult and time consuming.

5.2.3.4 Air-Lift Samplers

There are a number of adaptations to the basic method of applying air pressure to a water well to force a water sample out of a discharge tube. A high-pressure hand pump and any reasonably flexible tubing can be used as a highly portable sampling unit. A small air compressor and somewhat more elaborate piping arrangements may be required at greater depths. This method is cost effective for deep, small diameter wells. The primary limitations to this type of sample removal are the potential alteration of water quality parameters and volatilization of organic compounds, the amount of air pressure that can be safely applied to the tubing, and finding a suitable source of compressed air which is not contaminated by oil from the compressor. Inert gases, such as nitrogen, may be used instead of air to reduce contamination and volatilization of organics.

5.2.4 Sample Collection

The first bail or pumped volume of water sample retrieved should be used to: (1) fill VOA vials, and/or (2) provide a sample for field tests to be conducted. Field tests that may be performed on each ground water sample include temperature, pH, salinity, specific conductivity, color description, dissolved oxygen, and turbidity. The parameters may be determined by using electronic testing devices specifically designed for the particular parameter.

Temperature may be measured with a thermometer but this measurement is commonly incorporated into an instrument which is capable of testing other parameters such as salinity and conductivity. These meters, commonly called SCT (salinity, conductivity, temperature) meters, are easy to use. A single probe is placed into a sample of the water and the measurements read on three separate dials controlled by a selection knob. Turbidity is measured using a turbidity meter and color through use of a colorimeter. Alternately, these parameters may be described qualitatively such as:

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"light brown, slightly cloudy." Many models of pH meters are available. The pH probe is placed in the water sample and the pH value is read either on a dial or a digital display. Dissolved oxygen is determined in a method similar to pH. Careful calibration and operation of meters and maintenance of probes are required for field instrumentation.

The ground water sample used for field tests may be collected from the pump or bailer in a disposable plastic bottle. A reusable container must be carefully cleaned and decontaminated between uses. The sample is discarded after testing unless provisions of the safety plan or other regulations prohibit such action.

Subsequent bails or pump flow should be used to fill the remaining sample containers. To help avoid any potential constituent stratification in the water sample from affecting the representative nature of the samples, the sample container should be filled by pouring a small portion of water into each container alternately until all of the containers are full.

To reduce disturbance of sediments at the bottom of the well and minimize volatilization of organics, the bailer or pump inlet tube should be lowered carefully into the well to prevent substantial agitation of the water column. Pumping rate should also be adjusted to lessen agitation. The number of bails or pumping time used to fill the sample bottles should be minimized.

5.2.5 Sample Filtration

Because suspended particles are not generally transported by ground water, it is important to filter ground water samples designated for metals analyses so that an accurate determination of dissolved metal concentrations may be obtained. Surface water samples typically are not filtered prior to analysis.

The procedures outlined below have been formulated based on practical experience and consideration of chain-of-custody and other requirements.

Prior to sample filtration, all equipment used in the procedure should be cleaned according to procedures described in Technical Memorandum No. 11. Samples for filtration are collected in pre-filtration sample bottles included in the set of bottles for each sampling station. A temporary sample label should be affixed to the pre-filtration bottle. Following sample collection the pre-filtration sample containers are placed on ice in a separate cooler and transported to the location where the filtration will be performed.

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Many types of filtration apparatus are marketed and several may be satisfactory for use. A filtering apparatus can be assembled with the equipment and procedures described below:

1. Vacuum pump (electric pump or water faucet eductor)
2. Vacuum tubing with stop-cocks, t-connectors
3. Buchner funnels (one per sample)
4. 0.45-micron membrane filters
5. Glass fiber prefilters
6. One-hole rubber stoppers, reamed to facilitate funnel insertion (one per sample)
7. 1000-ml Erlenmyer side-arm filter flasks (one per sample)
8. Acid-preserved sample bottles (one per sample)
9. Filter apparatus box (to support several flasks and tubing network)

A funnel and flask should be set up for each sample collected. Several samples may be filtered simultaneously using a branched vacuum tubing network with appropriate t-connectors and in-line stop-cocks. The side-arm of the flask is connected to the vacuum tubing which in turn is connected to the vacuum pump. A 0.45-micron membrane filter is placed into the Buchner funnel using the glassine paper spacers to pick up and insert the filter. Avoid bending, folding, or touching these membranes. The glass fiber prefilters are then placed over the 0.45-micron filters. The pre-filter serves to remove large solids and greatly reduces filtering time. When all filters are in place, the vacuum pump is started. The stop-cock to the filter flask is opened slowly to seat the membrane. Approximately $\frac{1}{2}$ to $\frac{3}{4}$ inch of sample water is poured into the funnel and checked to see that the filter membrane is seated properly. If no cracks or air bubbles are observed and the membrane is tight against the funnel strainer, additional sample is added. If the membrane is ruptured or does not seat properly, the filtering process should be stopped and repeated with a new membrane. Sample water that has passed the ruptured membrane should be refiltered.

When all of the sample has been filtered, the stop-cock is slowly closed and the funnel is removed from the flask. The filtrate from the Erlenmyer flask is poured into the appropriately labeled and preserved sample bottle. The bottle is then placed into the cooler with the other samples and the log book and chain-of-custody forms are filled out. The used filter should be discarded and the used funnel and flask placed into a plastic bag for storage until they can be cleaned.

As an alternative to this technique, a disposable filtering system may be used. The principles of operation are the same as those described above. To eliminate the need to clean the contaminated equipment, these systems provide an inexpensive, disposable filter cup and strainer with a 0.45-micron filter and a glass fiber pre-filter in place, attached to a

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disposable filtrate container. This unit attaches directly to the vacuum pump.

5.2.6 Safety Considerations

In addition to observing all applicable health and safety directives contained in the site safety plan, the following points should be emphasized:

1. Organic vapor concentrations may accumulate in wells and produce concentrations much higher than ambient or expected levels.
2. Use of bailers increases the likelihood of contact with contaminated water or fluids due to spillage. In addition, the bailer rope may cut or tear lightweight rubber gloves. Therefore, appropriate protective gear, including goggles, should be worn by all sampling personnel.
3. Bailing is a strenuous activity and may easily tire individuals wearing protective gear.

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FIGURE 5-1

CHECKLIST FOR SURFACE WATER SAMPLING PROCEDURES

- ☐ 1. Select locations for sampling (Section 5.1.2)
 - ☐ general areal coverage
 - ☐ vertical profile
 - ☐ environmentally sensitive areas
 - ☐ proximity to human activities
- ☐ 2. Determine analyses to be performed
- ☐ 3. Obtain sample bottles with correct preservatives and shipping containers (refer to Technical Memorandum 2)
- ☐ 4. Obtain labels, chain of custody forms and other documentation (refer to Technical Memoranda 2 and 10)
- ☐ 5. Select appropriate sampling equipment (Section 5.1.2)
 - ☐ pond sampler (or dipper)
 - ☐ Coliwasa
 - ☐ weighted bottle
- ☐ 6. Clean sampling equipment (refer to Technical Memorandum 11)
- ☐ 7. Package sampling equipment (refer to Technical Memorandum 11)
- ☐ 8. Package sample bottle sets (refer to Technical Memorandum 2)
- ☐ 9. Collect samples (Sections 5.1.3 - 5.1.5)
- ☐ 10. Conduct field tests, if any
- ☐ 11. Label and package sample containers for shipment (refer to Technical Memoranda 2 and 10)
- ☐ 12. Transport samples to shipper (refer to Technical Memoranda 2)
- ☐ 13. Sign and date chain of custody form, reseal container, and relinquish to shipper (refer to Technical Memorandum 2)

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FIGURE 5-2

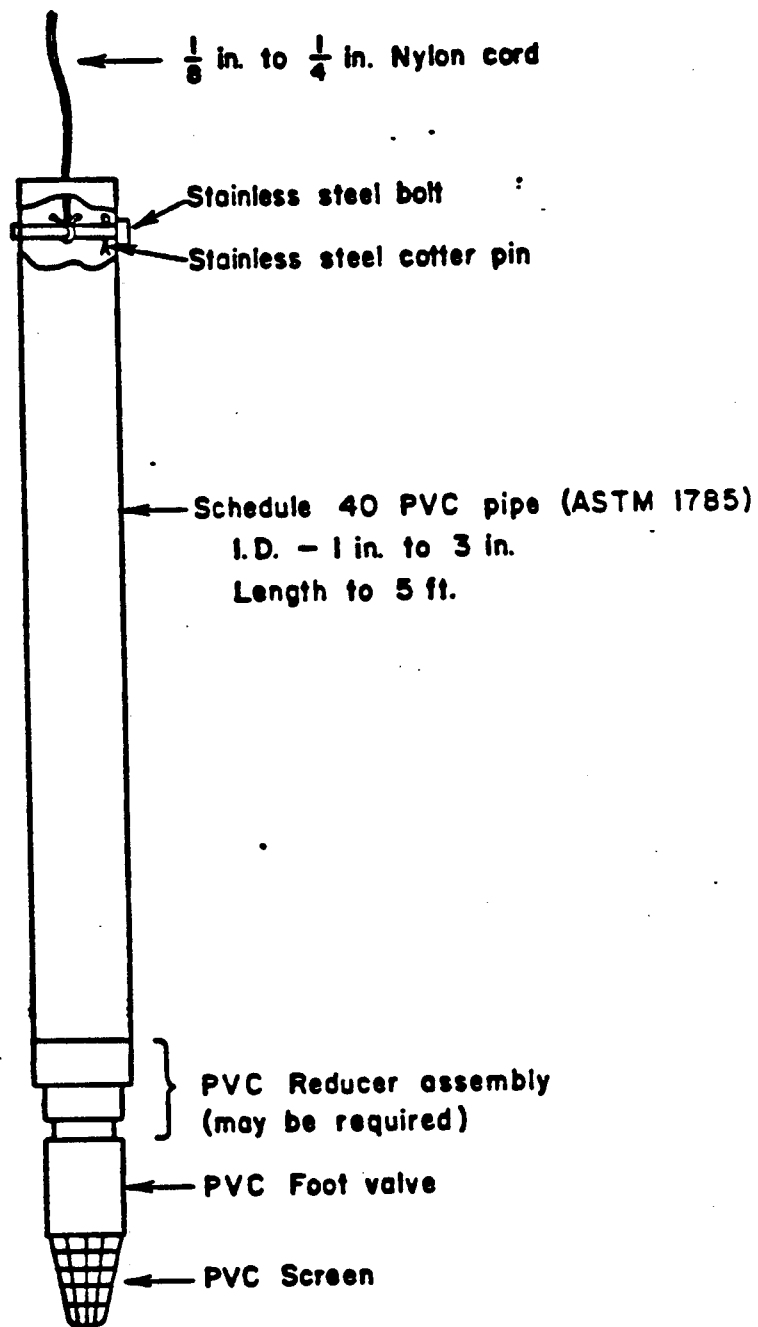
CHECKLIST FOR GROUND WATER SAMPLING PROCEDURES

- ___ 1. Select locations for sampling (Section 5.2.1)
 - ___ monitoring wells, installed
 - ___ existing wells, on site
 - ___ existing wells, off site
- ___ 2. Determine analyses to be performed
- ___ 3. Obtain sample bottles with correct preservatives and shipping containers (refer to Technical Memoranda 2 and 10)
- ___ 4. Obtain labels, chain of custody forms, and other documentation (refer to Technical Memorandum 2)
- ___ 5. Select appropriate flushing and sampling equipment (Section 5.2.3)
 - ___ bailer
 - ___ suction lift pump
 - ___ submersible pump
 - ___ air-lift sampler
- ___ 6. Clean sampling equipment (refer to Technical Memorandum 11)
- ___ 7. Package sampling equipment (refer to Technical Memorandum 11)
- ___ 8. Package sample bottle sets (refer to Technical Memorandum 2)
- ___ 9. Measure ground water elevation (Section 5.2.2)
- ___ 10. Flush well prior to sampling (Section 5.2.3)
- ___ 11. Measure ground water elevation (Section 5.2.2)
- ___ 12. Collect sample (Section 5.2.3)
- ___ 13. Conduct field tests, if any (i.e., pH, conductivity, temperature, etc.)
- ___ 14. Filter metals sample from ground water (Section 5.2.5)

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- ___ 15. Label and package sample containers for shipment (refer to Technical Memoranda 2 and 10)
- ___ 16. Transport samples to shipper (refer to Technical Memoranda 2)
- ___ 17. Sign and date chain of custody form, reseal container and relinquish to shipper (refer to Technical Memorandum 2)

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NOTE: ALL CONNECTIONS ARE
THREADED AND WRAPPED
WITH TEFLON TAPE.

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TECHNICAL MEMORANDUM NO. 5		PROJECT NO. K 82-4
WOODWARD-CLYDE CONSULTANTS CONSULTING ENGINEERS, GEOLOGISTS, AND ENVIRONMENTAL SCIENTISTS CENTRAL REGION		
DRN. BY: <i>JK 9-2-02</i> <i>1.2 R</i>	TYPICAL WELL BAILER	FIG. NO. 5-3

HAZARDOUS WASTE MANAGEMENT PRACTICE

TECHNICAL MEMORANDUM NO. 6 SOIL, SEDIMENT AND ROCK SAMPLING

6.1 Surface Soil and Sediment Sampling Procedures

6.1.1 Purpose

The purpose of this section is to provide procedures which may be used to obtain representative samples of surface soil and sediments. These procedures are intended for use in collecting environmental samples; however, care should be used in sampling because high concentrations of contaminants may be encountered. The following are general considerations for sampling surficial materials.

Samples of surficial materials are collected for analysis in order to provide data regarding the extent of contaminant migration as a result of: (1) transport of contaminated sediments off site and/or (2) the adsorption or reactivity (e.g., cation exchange capacity) of contaminants with surficial materials, and/or (3) the general chemical or physical nature of the surface sediments. Analysis of surface soil and sediment samples may serve to confirm or compliment data obtained from analysis of surface waters.

6.1.2 Sampling Methods and Equipment

Collection of surficial samples may require no special sampling equipment or highly detailed procedures. Samples may be obtained on or in the vicinity of a hazardous waste site and should be representative of the nature of local surface soils or sediment.

Soil and sediment samples naturally compliment surface water samples; under most circumstances surface waters will directly influence contamination of surface soils. Therefore, it is recommended that surface soil or sediment samples be collected at or near the locations of surface water samples. If such a relationship cannot be made (for example, if the presence of water is intermittent), samples of surficial materials should be collected in drainage ways leaving a site, in areas where overtopping of a dike or flooding is likely to occur, or in areas of obviously contaminated soils. Samples of surficial materials should be collected from the ground surface to a depth of approximately 6 inches.

Determination of the number of samples to be collected will be made in the site sampling plan. Exact locations for sampling should not be dictated because site conditions at the time of sampling may limit access or reveal previously unidentified areas where sampling would be beneficial. Rather, general areas for sampling or particular site conditions which warrant a sampling should be identified and the selection of the sampling point left to the judgment of field personnel.

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Samples may be collected using a short, hand-pushed core tube or a stainless steel or polyethylene scoop or shovel. Disposable equipment is preferred, especially if the materials are heavily contaminated with oils, tars, or similar substances. Reused sampling equipment must be decontaminated between uses as described in Technical Memorandum No. 11.

6.2 Subsurface Soil and Sediment Sampling Procedures

6.2.1 Purpose

The purpose of this section is to provide procedures which may be employed in a subsurface sampling program to obtain samples of materials that are: (1) representative of subsurface conditions at the site, (2) appropriate to the types of analyses to be performed, and (3) cost effective toward meeting the goals of the project. The following general considerations should be used in selecting sampling procedures.

Sampling may consist of either a general survey or detailed exploration and may often encompass both. A general survey is designed to obtain preliminary information about subsurface conditions such as depth to rock and soil classification. Equipment often consists of hand-operated augers, probes, and samplers designed to provide quick identification of conditions through retrieval of small volume, disturbed samples. If undisturbed samples are required for analysis of soil properties, more elaborate equipment and stricter quality control procedures may be necessary. These samples may be submitted for physical analyses, such as permeability or chemical analyses, to identify contaminants in the soils.

Methods and equipment commonly used for soil sampling in geotechnical investigations are also used for hazardous waste site investigations. As was the case with procedures discussed in Technical Memorandum 3, determining the applicability of various soil sampling tools to particular subsurface conditions is a standard practice. Therefore, this memorandum does not present detailed explanations of sampling equipment design and operation. Rather, commonly used methods are discussed in terms of particular limitations or factors which may affect the uses of the methods for sampling potentially contaminated soil. Safety and quality assurance concerns are of prime importance and are addressed in separate documents.

6.2.2 Manual Sampling Methods

In general, hand sampling using manually operated equipment is most valuable as a general survey technique for shallow depths when precise data or high quality control is generally not required. The most common hand-operated samplers are augers, Porter, plug, tube, split-barrel or fixed piston samplers pushed or driven by hand. Hand augers are easily used at depths less than about 10 feet. Pushed samplers can be used to obtain samples within about 3 feet of the surface or, with appropriate extensions, ahead of an augered hole.

The advantages of these methods are low equipment costs, portability of equipment and relatively rapid acquisition of samples. Augers, tubes and split-barrel samplers can be easily decontaminated. Fixed-piston samplers generally require longer time to disassemble, clean and reassemble. Correlation of samples to depth can be very good when samples are retrieved at small intervals.

Disadvantages of the methods are evident in that relatively small volume, typically disturbed samples are obtained, samples may not be suitable for some laboratory testing procedures, and samples are retrievable only from relatively shallow depths. Care must be taken to prevent (to the extent possible) soil from upper portions of the hole from mixing with lower samples. This is most likely to be a problem when augers are used to advance a hole or obtain cuttings samples.

Because of the unpredictable disposal methods which have been used at many uncontrolled waste sites, sampling devices must never be forced into an abruptly hard material. The stiffness may be a natural lithology change, a rock ledge or cobble, or a buried drum. If resistance is encountered while augering or pushing a sampler, the procedure must be stopped. The log book entry will indicate the depth at which resistance was met (in addition to required log book information described in Technical Memorandum 10).

6.2.3 Bore Hole Sampling Methods

There are a large number of sampling methods and equipment which have been designed for obtaining soil samples at depth from bore holes advanced by drilling rigs (see Technical Memorandum 3 for discussions of drilling methods). Geologists and geotechnical engineers should be familiar with the method most suitable for a particular investigation. Several general types of sampling methods are commonly used; these techniques are discussed below in terms of sample quality, safety, and decontamination. Limitations (or advantages) indicated for the methods described in this section may be applicable to other methods of similar design and operation.

6.2.3.1 Sampling Auger Cuttings

Auger cuttings are commonly collected for chemical analyses (refer to Technical Memorandum 2 for discussion of sample containers). A stainless steel or plastic scoop can be used to obtain a sample from the cuttings pile. The shovel used by drilling personnel to move cuttings should be stainless steel.

Gloves and goggles will be the minimum protection during collection of samples. Under no circumstances will cuttings be handled without gloves, smelled or tasted to determine any physical property. After samples have been collected, they will be stored and shipped as specified in Technical Memorandum 2 and the site sampling plan.

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6.2.3.2 Sampling with Split-Barrel and Liner-tube Samplers

Samples obtained using split-barrel samplers are typically submitted for chemical analyses as well as logged for soil type. Liner tubes may be incorporated in certain samplers to contain samples temporarily. The liner tubes may be constructed from brass, plastic or other inert materials which may be used to store and transport the samples. Samples can be transferred from the sampler to the appropriate sample container using either the liner tube or a stainless steel or plastic spoon (refer to Technical Memorandum 2).

Gloves and goggles are the minimum protection required during opening of the sampler and sample examination and transfer. Under no circumstances will a sample be handled without gloves, smelled or tasted to determine physical properties.

The sampler must be decontaminated between uses if chemical analyses are to be performed on samples or the bore hole will be converted to a monitoring well. Refer to Technical Memorandum 11 for decontamination procedures.

Samples will be placed in appropriate containers, stored and shipped as specified in Technical Memorandum 2 and the site sampling plan.

6.2.3.3 Sampling with Shelby Tubes

Steel Shelby tubes are commonly coated inside and out with lacquer or zinc chromate to prevent corrosion. Chemical constituents of these protective coatings are likely to be transferred to the sample to some degree and can adversely affect subsequent analyses. If chemical analyses are to be performed, the soil must be extruded from steel tubes immediately after sampling. Samples for chemical analysis must not be stored and shipped in the steel Shelby tubes. After the sample has been extruded, the outer surface of the sample must be scraped off (using a stainless steel knife) to a depth of about 1/2 to 1 inch. This procedure will eliminate the possibility of contamination of the analyzed sample from Shelby tube coatings and drilling muds. The area where Shelby tubes are extruded and equipment used must be kept clean and decontaminated. Aluminum foil or plastic may be used as a disposable cover for surfaces upon which samples will be laid. Plastic Shelby tubes are available and may be appropriate for sampling and storage of some materials.

To attain the greatest level of security against cross contamination, Shelby tubes should not be reused. If reuse is necessary, the Shelby tube must be thoroughly decontaminated if the subsequently sampled material is to be chemically analyzed. Less rigorous cleaning is required if physical test samples are to be collected. Procedures for decontamination are described in Technical Memorandum 11.

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Samples destined for chemical analyses will be transferred to appropriate sample containers, stored and shipped as specified in Technical Memorandum 2 and the site sampling plan.

Shelby tubes are often used to collect relatively undisturbed samples for physical testing. The site sampling plan and/or site safety plan will indicate how such samples will be shipped. It may be feasible to store and ship samples for physical testing in the Shelby tube.

If this technique is used, the sampler must be sealed using standard procedures for geotechnical investigations. Generally plastic caps and tape are sufficient. The exterior of the Shelby tube must be decontaminated (see Technical Memorandum 11 for procedures). The tube can be placed into a plastic bag to further guard against accidental escape of contaminated soil. Tubes are stored and shipped according to procedures described in Technical Memorandum 2 and the site sampling plan.

6.2.3.4 Other Samplers

Many other types of soil samplers are in common use. Among these are the fixed-piston tube sampler, Denison Sampler, Pitcher Sampler, liner-tube samplers and others which have been designed to meet specific requirements of particular geotechnical investigations. Further information on many samplers and sampling methods may be found in the references listed at the end of this memorandum. These pieces of equipment are typically of complex design and the need for decontamination on hazardous waste site investigations will probably prohibit their use for obtaining samples for chemical analysis primarily due to time constraints as well as difficulty in cleaning various components.

If used for hazardous waste site investigations, the same safety and quality insurance procedures must be applied as described for the other sampling methods. The site sampling plan and site safety plan will address these factors.

6.3 Subsurface Rock Sampling Procedures

6.3.1 Purpose

The purpose of this section is to discuss procedures which may be used to obtain samples of rock from a bore hole. Details of procedures commonly used in geotechnical and geologic investigations are not included. General considerations for subsurface rock sampling are as follow.

The reasons for embarking on a program of sampling of bedrock formations are generally the same as for other subsurface sampling--to obtain samples that are representative and appropriate for desired testing in a manner that satisfies the goals of the project.

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A careful, thorough preliminary survey of regional and site geology and pertinent literature should be made. Expecting ahead of time the conditions that may be encountered allows efficient planning and may save costly down time or damage to equipment that is used in conditions for which it was not designed.

As with soil and sediment sampling, retrieval of adequate rock samples from the subsurface can be accomplished only by using complicated sampling tools and power equipment. Therefore, rock sampling is a technique that is part of a detailed subsurface investigation.

6.3.2 Rock Coring Methods and Equipment

Rock samples are not generally analyzed for chemical contaminants. However, quality assurance procedures are still important because rock coring is often performed in aquifer zones. Contamination of the aquifer or water bearing unit either vertically or between bore holes should be prevented. Monitoring wells are often installed in cored holes; therefore, adequate decontamination of equipment is required.

Core barrels are available in a variety of designs and sizes. In general, subsurface conditions dictate selection of the particular method and such determinations are routinely made by geologists and geotechnical engineers. Additional information about various methods can be found in the references.

Decontamination of core barrels may not be as time consuming as for some soil samplers because core barrel design may not be as complicated. Procedures for decontamination are discussed in Technical Memorandum 11 and will be detailed in the site sampling plan.

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**WOODWARD-CLYDE CONSULTANTS
HAZARDOUS WASTE MANAGEMENT PRACTICE
TECHNICAL MEMORANDUM NO. 7**

HAZARDOUS WASTE SAMPLING

REVISION 0

August 1982

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HAZARDOUS WASTE MANAGEMENT PRACTICE

TECHNICAL MEMORANDUM NO. 7 HAZARDOUS WASTE SAMPLING

7.1 Purpose

The purpose of this memorandum is to present procedures which may be used for sampling hazardous waste materials. Sampling of hazardous wastes is potentially dangerous and requires special care. Specialized equipment and experienced personnel may be required for certain procedures. General considerations for sampling hazardous wastes are described below.

Due to the variable and unknown nature of hazardous waste samples, persons engaged in such sampling should be familiar with the wide range of methods and equipment available. In order to adapt to unforeseen situations, it is recommended that the publications listed in the "References" section be reviewed.

Contaminant concentrations of up to 100 percent may be encountered in hazardous samples obtained from ponds, pits, lagoons, leachate streams, waste piles, tanks, drums or other closed containers. Depending on the type of container and location of the sample, the risk to personnel from exposure to potentially harmful substances while obtaining samples is greater than at any other time of the site investigation. It is imperative to employ procedures and equipment that adequately protect personnel, minimize the risk of exposure, and allow quick, efficient sample retrieval. It should be noted that depending on concentrations of contaminants, routine soil or water samples (described in Technical Memoranda 5 and 6) may also be considered hazardous materials. If it is anticipated that soil or water samples may be classified as hazardous; personnel should refer to the applicable parts of this Technical Memorandum as well as those for soil or water sampling.

7.2 Technical Approach

The type of sampler and associated equipment used will vary with the physical and chemical properties of the waste. Subsequent sections of this memorandum indicate the equipment recommended for each type of waste and important aspects of sampling procedures. For a more detailed description of samplers (including design) and their uses, refer to the EPA publications listed in the "References" section of this Technical Memorandum.

In general, any method used or equipment selected for use in sampling should satisfy the following requirements:

1. Personnel wearing all types of protective gear should be able to accomplish sampling without compromising their safety.

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2. The possibility of synergistic reactions resulting from chemical reaction or concussion should be avoided.
3. Cross contamination of samples should be avoided. Sampling equipment should be easily decontaminated or be disposable.

In addition to the packaging procedures described in Technical Memorandum 2 a sample container for hazardous waste should be placed temporarily into a plastic bag secured at the container neck with a rubber band. This procedure reduces contamination of the outer surface of the sample container. The bag is removed once sampling is completed and the container sealed. The outer surface of the sample container is washed prior to packing for shipment to remove any remnant contaminants.

A typical sampling team should consist of two or more members. One team member will remain in a designated safe area but will wear the required protective gear and be ready to respond in case of emergencies.

The procedures and equipment described in this Technical Memorandum generally follow those recommended by EPA. However, due to the vast number of possible waste types, the Technical Memoranda cannot address procedures specific to all waste types or impoundments. Additional study and research should be conducted by personnel involved with highly toxic or highly concentrated wastes or drum sampling. The EPA is a source of information, and private contracting firms exist which specialize in this type of work.

Prior to using the specialized equipment and procedures required for some sampling tasks, training programs will be required.

Information contained in this section (7.2) is applicable to all procedures subsequently described. The delicate nature of sampling particular types of hazardous wastes requires elaboration or additional information. Therefore, each part of the memorandum contains a separate Purpose and Technical Approach section so that variables and precautions specific to each waste type can be emphasized.

Checklists of equipment and procedures for each type of waste sampling are included for each section. These checklists provide a concise list of procedures and equipment required for each type of sampling procedure. References are made to the specific sections of the Technical Memoranda which describe the given procedure or piece of equipment.

7.3 Sampling from Drums or Closed Containers

7.3.1 Purpose

Sampling and handling of drums/closed containers is a potentially very hazardous operation. Therefore, an experienced contractor specializing in those sampling techniques should be obtained to conduct such operations.

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The following procedures are included for evaluation of procedures proposed by potential contractors. A checklist of procedures is presented in Figure 7-1.

Drummed or containerized wastes represent the greatest potential danger to sampling personnel. The physical state of some drums may have deteriorated to the extent that attempts to move or open them could result in rupture of the drum and uncontrolled release of contents. Identifying labels are commonly absent; therefore, the nature of drummed waste may be completely unknown and its potential reaction to sampling efforts unpredictable. Detailed procedures with contingencies for any likely emergency situations will be presented in the site safety plan and site sampling plan.

7.3.2 Technical Approach

7.3.2.1. Safety Considerations

Unless information is available to the contrary, closed drums should be assumed to contain toxic and extremely hazardous materials. Protective clothing should be worn during drum opening, sampling, labeling, and packaging of drummed wastes. Required protective gear includes full-coverage splash suits or totally encapsulating suits, and self-contained breathing apparatus. Personnel involved in drum movement, opening, or sampling should be fitted with an external harness and lifeline for retrieval in case of injury. Only personnel directly involved with sampling should be allowed near the activity.

Drums may be pressurized or under vacuum seal. Extreme caution should be used when opening a bulging drum until pressure has been relieved. Opening the bung of a drum with steel tools could produce a spark which might cause detonation of explosive gases in the drum. Non-sparking, brass bung wrenches are available and should generally be used to prevent potential explosions.

Air quality monitoring will be performed using an OVA and/or combustible gas meter. Readings should be taken in the ambient air prior to the initiation of container opening, at the container opening immediately after entry, and periodically during sampling. Refer to Technical Memorandum 4 for descriptions of monitoring equipment and their uses.

If during opening or positioning of drums there is evidence of leakage, rupture, or potential loss of control over the drum, personnel will evacuate the area to a safe upwind position and assess the situation. If during sampling there is an indication of any kind of reaction (e.g., smoke, flame, sparks, color changes of liquids), sampling activity will cease and personnel will evacuate to a safe area immediately. In either case, the site manager and site safety officer will be notified of the situation so that they may respond as needed.

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7.3.2.2 Drum Selection

Selection of containers for sampling is contingent upon a number of factors including accessibility, background data, container conditions, and enforcement or cleanup activity requirements. Identification of the drums or containers to be sampled will be considered during the development of the site sampling plan. The following procedures may be used to facilitate the selection process.

An inventory of containers, including their number and condition, should be made. An exhaustive search for existing manufacturer, shipment, or disposal data should be performed in an attempt to identify drum contents prior to the selection of containers for sampling. If such data are available, sampling may be used to confirm this information. If drum contents are not known and requirements do not mandate the sampling of each container, a random sampling approach may be used. This random selection will be defined by the scope of the investigation and the available budget. In certain cases, all drums will be sampled, either discretely or compositely, to identify their contents.

The first step of a random approach is to identify readily accessible drums. These include drums whose physical location and condition pose no threat to sampling personnel, drums which do not have to be moved prior to opening, and drums which may be easily opened using a remote opening device.

Each of the drums identified as being accessible for sampling is assigned a consecutive number and a random number table can be used to choose the drums to be opened and sampled. The quantity of drums to be sampled will be specified in the site sampling plan.

A photographic record will be made of all drums from which samples are taken. The accompanying logbook entry will contain a detailed written description of the drum condition and step-by-step narrative of the selection, opening and sampling procedures.

7.3.2.3 Movement of Drums

Because of the possibility of accidental puncture, rupture caused by deteriorated physical condition or potential instability of contents, drums should be moved only to the extent necessary to allow safe sampling or to provide required staging. Isolated drums may not require movement if their location is accessible, stable, and not otherwise dangerous to sampling team members. Drums may require repositioning to place the bung or proposed point of penetration to the highest possible orientation in order to reduce possible leakage of liquids or granular solids.

Drums should not be opened in close proximity to any other site activity or while stored or stacked with other drums. This is especially critical when

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contents of drums are unknown and potential reactions caused by interaction of their contents cannot be predicted. If such situations exist, it is necessary to isolate the drum being tested. The EPA recommends a safety zone of several hundred yards between the drum opening area and the drum stacks. If it is not possible to isolate the drum opening area from the drum storage area by several hundred yards, the largest feasible distance which doesn't compromise the safety of individuals on or near the site should be used. Routes of drum-moving machinery should be clearly marked, as should the opening area and any staging or storage areas (refer to Section 7.3.2.8).

Drums may be moved using the following pieces of equipment. A small front-end loader (with about a 1-cubic yard capacity bucket) can be used to move drums that are accessible and of sufficient physical soundness to allow manipulation into the bucket. This procedure requires team members to tip or rock the drum by hand or attach a sling to the barrel which is then lifted with the bucket. Forklifts can be used to move palletized drums but this method also requires sampling team personnel to move the drum onto the pallet by hand. A remote method of picking up drums is preferred, especially if the physical condition of the drums is poor.

One device which has many advantages over the two previously discussed devices is an excavator (backhoe) equipped with a hydraulic grapppler. This piece of equipment is preferred because:

1. The operator is farther from the drums than personnel manipulating drums by hand.
2. The cab (if present) provides splash protection for the operator.
3. The operator can use an air-line respirator with supply tank carried on the machine. This provides increased work time and causes less fatigue than self-contained breathing apparatus. (The breathing protection required for drum moving procedures will be specified in the site safety plan.)
4. If a drum should explode, the force of the blast would be directed out the top and bottom of the drum and either away from the operator or deflected by the grapppler arm.
5. If a drum should catch fire, begin expanding, fuming or releasing contents, it can be quickly dropped (perhaps away from the drum stack) and the operator can back his machine away from the danger area rapidly.
6. The drum grapppler can pick up drums stacked in any orientation and move them more quickly than other operations. Also, if a drum leaks, the grapppler can be rotated to stop the discharge.

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Disadvantages of the hydraulic grapppler may be higher cost of operation and non-availability in some areas. However, in many cases its use may be justified by the increased safety factor.

7.3.2.4 Container Opening Procedures

Remotely controlled container opening devices are preferred because they reduce the safety risk to sampling team members. Use of such equipment does increase the amount of time and supplies required for sample collection. If hand-opening cannot be avoided, non-sparking bung wrenches must be used and entry to the drum must be attempted only by opening the bung. Drums must never be penetrated using hand-held tools.

If drums have been moved prior to opening, sufficient time must be allowed for drum contents to settle before proceeding. During placement of remote opening equipment, all possible safety precautions should be observed. Section 7.3.2.1 describes safety procedures specific to drum sampling. Further information can be found in the WCC Hazardous Waste Health and Safety Manual.

The EPA National Enforcement Investigation Center (NEIC) has developed two remotely controlled drum opening devices for use on hazardous waste site investigations. The NEIC penetrating sampler uses a hydraulic mechanism to pierce the side of a drum. The device then acts to seal the opening while a sample is withdrawn through the penetrator's hollow stem. NEIC's bung remover is operated by compressed air and consists of an impact wrench equipped with a non-sparking socket which spins the bung off of the drum. It can be used on top-mounted or side-mounted bungs.

EPA's Field Investigation Team (FIT) contractor, Ecology and Environment, Inc., (E&E) has modified the original NEIC designs. The E&E penetrating sampler pierces the drum from the top and is not left in the opening. In place of a bung removal device, E&E has developed an air-powered drill that cuts through the bung or drum top.

Other types of equipment may be available which perform similar functions. Also available are drum deheading devices which cut the top off a drum and a bronze spike which attaches to a backhoe arm and is used to puncture a drum. Regardless of the type of equipment used, personnel should be trained on its function and have the opportunity to perform a "dry run" on an empty or water-filled drum using required equipment and protective gear.

7.3.2.5 Sampling Techniques - Liquids

The technique described in this section is one that is simple and should be easy to accomplish even in maximum protective gear. Other procedures may be designed and used with the approval of the Project Manager. Any methods should conform to safety and sample QA/QC requirements.

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After the drum has been opened, a 4-foot length of glass tubing, 6 mm to 8 mm I.D., is inserted through the opening into the liquid contents. The top end of the tubing is blocked with a thumb or rubber stopper and the tube is withdrawn slowly from the drum. A visual observation of the sample is made as the tube is withdrawn to determine if multiple liquid phases are present in the drum and to detect any reaction of drum's contents. If the glass tubing becomes clouded or smokey, the sample should be released back into the drum, and the glass tube removed immediately and properly disposed on site. This condition indicates the presence of caustics or hydrofluoric acid which require the use of rigid polyethylene or teflon tubing to obtain samples.

A sample container is held by the second member of the sampling team at a position which enables the sampler to place the open end of the tubing over the mouth of the sample container. Wooden tongs can be used to grasp the contaminated end of the tubing and guide it. Releasing the thumb or stopper allows the sample to flow into the container. The process is repeated until adequate volume of sample is obtained. When sampling is completed, the glass tube is discarded inside the drum. (The tube may be broken so that its entire length will fit inside the drum.)

To prevent drum material spilled on gloves from contacting material from any other sampled drums, disposable gloves are worn over the chemical-resistant gloves and are discarded after each sampling task.

7.3.2.6 Sampling Techniques - Solid or Granular Wastes

If the size of the opening permits, samples are obtained using a disposable polyethylene or stainless steel scoop.

A brass spoon attached to a 2-foot to 4-foot length of wooden dowel is used to obtain a sample through a bung hole or other small opening. The use of a thief sampler is not recommended because friction and/or percussion associated with that type of sampling equipment might cause a reaction.

If a solid layer is encountered beneath liquid in a drum, it may be a hardened sludge or a more active material such as metallic sodium. To obtain a small sample of an unknown solid layer, a section of glass tubing is pressed into the sample to remove a small core of material. The sample can be carefully removed from the tube using a stainless steel spatula. Care should be taken to prevent the sample from contacting water. Any changes in color of the material upon contacting air should be noted.

7.3.2.7 Sealing Opened Containers

Replacing the bung on the drum is the easiest and most positive means of sealing a drum after sampling. If the bung cannot be used, or a penetrator was used to open the drum, the hole can be sealed using a wood or neoprene

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stopper. If neither of these methods provides adequate sealing, the drum should be placed into a larger sealable container (overpack).

7.3.2.8 Drum Storage Areas

Drums may be temporarily stored or "staged" prior to opening and sampling. This procedure will facilitate a coordinated sampling effort by allowing drum movement to proceed while the more time consuming sampling is performed on drums obtained from the staging area. The drum staging area must be located a sufficient distance from the drum opening area to prevent any opening accident (e.g., fire, explosion) from causing a chain reaction with staged drums. The actual distance may be affected by constraints of site boundaries or other operations.

After drums have been sampled, they should be stored prior to remedial action. The same area used for staging can also be used for storage with specific locations designated for each status.

Drums placed in staging or storage must not possess leaks or structural damage which may result in leaks, unless they are overpacked. Chemical reactions between various drum contents should be prevented. If contents are known, drums containing materials known to be non-reactive with each other can be stored together. Drum staging and storage areas should be clearly marked.

7.4 Sampling from Surface Impoundments (Pits, Ponds, Lagoons)

7.4.1 Purpose

The purpose of the following section is to provide procedures which may be used to obtain samples of hazardous waste from surface impoundments. A checklist of procedures is presented in Figure 7-2. General considerations for sampling such hazardous wastes are as follow.

Sampling sludges, water or other liquids from surface impoundments is a common requirement for hazardous waste site investigations. The complexity of the sampling program is contingent upon the desired results. They may be intended to simply establish the types of contaminants present, to provide data required for the design of containment or disposal facilities, or to provide information sufficient to support proposal of reclamation efforts for certain waste constituents. Procedures cannot be generalized to meet the requirements of all investigations. Each site will present unique parameters for design of the sampling program. Techniques described in this section are meant to be used as models. Site-specific procedures will be detailed in the site sampling plan. The safety of the sampling team members should always be considered in the design of the sampling procedures.

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7.4.2 Technical Approach

7.4.2.1 Safety Considerations

Air quality in the immediate vicinity of impoundment surfaces may be considerably poorer than the ambient or off-site air quality. An organic vapor analyzer will be used when sampling from impoundments to continually monitor organic vapor concentration.

Appropriate splash and respiratory protection will be worn during sampling. The required equipment will be specified in the site safety plan. Contact with liquids from impoundments should be avoided and protective suits will be decontaminated as soon as possible following any contact with contaminated liquids. Cartridge-type respirators or self-contained breathing apparatus may be specified, depending on contaminant concentrations detected in air samples.

Access to the impoundment may present unique safety problems. There may be instances where mud flats, bogs or other soft ground conditions prevent easy access. Under no circumstances will personnel walk onto such unstable areas. Wooden planks or metal sheets placed on the ground may be one method of providing safe access. Remote sampling may also be considered where access is limited.

Catwalks or other existing structures over or adjacent to an impoundment should be carefully examined for structural soundness before being used by personnel.

Bank sampling may be inadequate for large surface impoundments or in areas which have limited access. In these areas a boat or barge may be designed to carry sampling team members onto the surface of the impoundment. The use of a boat presents increased safety hazards to personnel and increases the work effort due to the logistics of decontamination. The boat should incorporate a towing system which does not rely on personnel in the boat for supplying power to move the vessel. Safety railing around the perimeter of the deck is required, as is a non-skid deck surface and a lifeline system for each team member.

7.4.2.2 Sample Selection

As an initial procedure, a few samples may be obtained at different points around the perimeter of an impoundment. Data from analyses of these samples will provide an indication of the general type of contaminants present and an indication as to the spatial variation in material properties or contaminant concentrations. Collection of more detailed information will require a more comprehensive sampling program. To adequately delineate the nature and distribution of contaminants, samples should be obtained from representative locations in the impoundment, both

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areally and at depth. Stratification of liquids is common and lack of data concerning the "waste materials" may lead to inadequate remedial actions.

If an impoundment is large, a random sample selection procedure may be instituted for areal as well as vertical sample selections. The impoundment is divided into grid sections, both in horizontal and vertical dimensions; each grid section is assigned a number. Samples may be taken from each grid section or from grid sections selected using a random number table.

The rationale for the sampling program, the number of samples, and locations for retrieving samples will be specified in the site sampling plan.

7.4.2.3 Sampling Techniques - Liquids

Methods used for obtaining samples of water or liquids from surface impoundments are generally similar to methods described for surface water sampling in Technical Memorandum 5. Because higher concentrations of contaminants are likely, more thorough decontamination procedures will be required to prevent cross contamination.

Sampling from the bank of an impoundment is the safest and easiest procedure but resulting samples may not be representative, particularly if the sampling device could not be extended to reach across the entire surface area of the impoundment. Other access can be obtained in accordance with required safety considerations.

The most convenient technique for retrieving liquid samples is to use a glass, Teflon or polyethylene beaker attached to a wooden rod or telescoping aluminum pole (commonly called a pond sampler) to scoop up the sample. Samples are easily transferred to an appropriate sample container. This method is restricted to obtaining samples at the surface of the impoundment. It can be employed from any type of access.

If access is made to a position above the impoundment, for example, on a barge, a weighted bottle sampler can be used to obtain samples at vertical intervals beneath the liquid surface. A Coli-wasa sampler can also be used. (These two samplers are described in Technical Memorandum 5, Section 5.1.2.) Neither of these samplers are generally considered to be disposable and their working parts will require careful cleaning after each use. If liquids in the impoundment are of high viscosity, they may not readily flow into these samplers. In such cases, a tube sampler or double-tube grain sampler as described in Sections 7.3.2.5 or 7.4.2.4 may be used to obtain samples.

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7.4.2.4 Sampling Techniques - Sludges, Tars and Viscous Substances

The pond sampler described in the previous section may be used to scoop substances from the bottom of an impoundment and transfer the sample to the appropriate sample container. A disposable stainless steel spoon may be needed to facilitate transfer of sample. If the sampler cannot be thoroughly decontaminated between samples, the beaker should be disposed and a new one attached.

If the viscosity of the substance prohibits the use of a scoop-action sampler, a length of 1 to 2-inch diameter (or larger) PVC or stainless steel pipe may be used as a push-tube sampling device. The effectiveness of this type of sampler will depend upon the nature of the sampled material. Soft materials which are easily penetrated may flow out before the sampler can be retrieved completely. Placing a threaded cap on the end of the pipe and filling the space between the waste sample and the top of the pipe with water before tube withdrawal will increase the amount of material recovery. Very sticky or hard substances may not enter the sampler under manual force or may do so only slightly. The amount of force which can be applied to the pipe will depend on the particular situation. Some materials can be retrieved successfully with a push-tube sampler but do not flow readily into a sample container. If the sample must be scraped to remove it from the sampling pipe, a stainless steel knife or spatula must be used and great care taken to prevent shavings from the sampling tube from mixing into the sample.

The Shelby tube sampler or a manually operated fixed-piston sampler, can be used to obtain sludge samples. It has many of the same limitations as a push-tube sampler, although the piston action should result in more effective sample retrieval. The major disadvantage of using a fixed-piston tube sampler or any other similar device is that the working parts will be difficult to clean adequately. The cost of this type of sampler would preclude disposal after each sample.

Because most surface storage impoundments are constructed with sloping banks or sides, it may be impossible to reach sludges from the bank. Therefore, the method of sampling and the ability to obtain full access to the impoundment will have direct bearing on the quality and representative nature of the samples which are to be collected. In addition, sludge depth and thickness should be considered in designing a sampling system technique which is capable of retrieving good representative samples.

7.5 Sampling from Storage Tanks, Tank Trucks and Tank Cars

7.5.1 Purpose

Sampling of storage tanks, tank trucks and tank cars is potentially a very hazardous operation. Therefore, only experienced personnel or an experienced contractor familiar with such operations and specializing in

those sampling techniques should conduct such sampling programs. The following procedures are included for evaluation of the adequacy of such a sampling program. A checklist of procedures is presented in Figure 7-3.

Many different sizes and types of structural storage facilities may exist at a hazardous waste site. The most commonly encountered structure is the above-ground storage tank similar to those found at oil refineries. On occasion it may be necessary to obtain samples from railroad tank cars or tank trucks. Each presents unique factors for sampling which must be addressed in the site safety plan and site sampling plan. The following sections are meant to be used as a guide. Project-specific designs will be developed as they are needed.

7.5.2 Technical Approach

7.5.2.1 Safety Considerations

Sampling from storage tanks and similar structures present certain safety hazards not generally encountered in other types of waste sampling. Often these factors are related to the structural integrity of the tank and the location of access points.

When sampling tank structures, it may be necessary to climb on them to obtain access. Storage tanks, tank cars, and trucks generally have entrance ports or points of access on the top of the tank.

A thorough inspection of the containment structure must be made to determine the soundness of the tank and any access ladders, catwalks or platforms on which sampling personnel must walk. If any uncertainty regarding safety exists, alternative approaches must be utilized.

Structures which are in poor physical condition often are rusted and therefore contain many openings through which sampling can be performed. Care should be taken to avoid snagging protective clothing or arms and legs on jagged metal edges. A tank which is open to the atmosphere is not likely to contain explosive gas mixtures or high concentrations of other vapors. Nevertheless, air quality monitoring will be performed with the OVA and combustible gas meters prior to sampling, especially if entry into the tank is required.

Access to the interior of a closed tank may be made through existing hatches or covers. Because of the potential for production of sparks or release of pressurized gases as the hatch is opened, the procedure must be performed by personnel wearing self-contained breathing apparatus and full-coverage splash protection. The individual performing the operation should proceed slowly and position himself to one side of the hatch to prevent his being struck if the hatch is blown open by internal pressure. If possible, some type of remote opening system, perhaps using ropes and

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Cooper et al (1967) and Papadopoulos et al (1973) developed a set of type curves for analyzing slug test data, particularly for tests run in materials which are confined (under artesian pressure). The field data are plotted as dimensionless head (arithmetic scale) versus time (logarithmic scale) and matched to a set of type curves. The match point values are substituted into simple algebraic formulated to obtain a value for K (Appendix 8-1).

Bower and Rice (1976) and Bower (1978) developed a technique for analyzing slug test data collected from completely or partially penetrating wells in unconfined aquifers. Their analysis involves a plot of residual head (logarithmic scale) versus time (arithmetic scale). A straight line is applied to the early-time data and used to calculate a value for K. An example of the use of this technique is presented in Appendix 8-2. A plot of the data and calculations are included.

Pressurized slug test methods have been developed for testing extremely low conductivity (10^{-8} cm/sec or lower) materials (Bredehoeft and Papadopoulos, 1980). Basically, the pressurized slug technique is a modification of the conventional slug test discussed previously. The advantage of the pressurized slug technique is the reduction of time required to perform a test in tight formations. This method involves creating an instantaneous pressure surcharge on drawdown in the test zone, then closing a valve to shut in the well. Based on the rate of decay of the pressure slug and the geometry of the test zone, the transmissivity, hydraulic conductivity, and storativity may be calculated.

8.2 Aquifer Pumping Test

8.2.1 Purpose

The purpose of this section is to briefly describe the use of aquifer pumping tests to evaluate aquifer characteristics. Aquifer pumping tests, commonly referred to as pumping tests, are used to determine certain characteristics and properties of water-bearing zones. Pumping tests provide results that are often more representative of the aquifer's characteristics than do slug tests.

Aquifer characteristics which may be obtained from pumping tests include hydraulic conductivity (K), transmissivity (T), and specific yield (S_y) for unconfined aquifers and coefficient storage (S) for confined aquifers.

Equipment, personnel and time commitments needed to conduct pumping tests are greater than those required for slug tests. Briefly, a pumping test consists of pumping one well and recording the drawdown in the pumping well and in other nearby observation wells.

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There are advantages and disadvantages of pumping tests. Some of these are listed below.

Advantages of pumping test:

- o A greater portion of the aquifer is tested and the results obtained may be more reliable and representative of the aquifer characteristics.
- o Coefficient of storage and specific yield values can be determined.

Disadvantages of pumping test:

- o In low permeability aquifers long-term pumping may be required to complete the test and obtain reliable aquifer characteristics.
- o Disposal of discharged water may require special provisions if the ground water is contaminated.
- o Test may be very expensive when compared to slug tests.

There are several types of pumping tests. The most common type is the constant rate discharge test (Todd, 1981). Variable rate tests are also employed under some conditions. Although the analysis is more complicated, any sort of temporal variations in flow rate can be accounted for by assuming the law of superimposition holds. Usually this is a good assumption. The most widely used variable rate tests are the step-drawdown test, the constant head test, and the air-lift pump test (Kruseman and DeRidder, 1976).

Another useful technique is injection testing. Injection tests, both constant rate and variable rate, are analytically identical to pumping tests except for considering the flow rate a surcharge on the aquifer rather than a withdrawal. The data quality is also similar. Although injection tests are commonly used in the petroleum industry (Earlougher, 1977), numerous applications exist in hazardous waste practice. Obviously, water sampling for hydrochemical characterization of the aquifer must be conducted prior to injection (or considered unimportant) in application of this technique. The injection fluid should be free of suspended solids and should be of equal or higher quality than the ground water at the test site.

One major advantage of this type of test is that contaminated ground water is not removed from the formation and, thus, is not a disposal problem. A potential disadvantage of the injection test is that in certain cases the injection well would have to be able to withstand some induced hydraulic pressure. Cases where the injection rate is large enough to elevate the water level above the well casing would require a sealed well head

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configuration and proper well construction so that there would be no leakage of injected fluid on the ground surface. These requirements may be relatively expensive and difficult to operate in the field without the necessary precautions. Once an injection system is working at a constant rate of flow, the data collected are analyzed in much the same way as those from an aquifer pumping test, except that water level buildup is used in the analysis instead of drawdown.

This memo briefly describes equipment, procedures and other factors which must be considered for constant-rate pumping tests. References which provide additional information are presented in the list of references. Ground Water and Wells (Johnson, 1966) is a field guide with many suggestions on how to perform the test. Ground Water Hydrology (Todd, 1981) and other references such as (Kruseman and DeRidder, 1976) provide analytical techniques and example problems of pumping tests conducted under different geologic conditions.

8.2.2 Equipment

The amount of equipment necessary to perform a constant-rate pumping test is greater than that used in a slug test. This is part of the reason why the aquifer pumping test is considerably more expensive. Equipment needed for a pumping test includes:

- o Pumping well and pump. Pumps are commonly of the submersible or turbine type. The pumping well should be properly developed prior to testing.
- o One or more observation wells hydraulically connected to the pumped aquifer and completed to the proper specifications for the particular test.
- o An orifice, weir, flow meter, container or other type of water measuring device to accurately measure and monitor the discharge from the pumping well
- o Sufficient pipe to transport the discharge from the pumping well away from the area to prevent infiltration in the area of influence of the pumped zone
- o Gate valve on the discharge pipe to control the pumping rate
- o Outlet near well head for water quality determinations and sampling.
- o Depth-to-water measuring devices for each observation well and the pumping well (This may include steel tapes, electric sounding probes, Stevens Recorders, or pressure transducers)

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- o A thermometer and other water quality equipment necessary
- o Watches capable of reading to the nearest second for all observers or a stopwatch
- o 3-cycle by 5-cycle log and 5-cycle semi-log graph paper
- o Pencils and forms for recording times and drawdown measurements at each well
- o Appropriate references and calculator for determinations in the field
- o A barometer or recording barograph

8.2.3 Pump Well Design

Design of the pump well is an important consideration in aquifer testing. In some cases an existing well will be used for pumping. When sufficient funds and conditions permit, a pumping well can be designed and constructed specifically for the test. The pumping well should be screened throughout the thickness of the aquifer to be tested with standard well screen. The well should be gravel packed, if necessary, to minimize sand production in unconsolidated fine-grained aquifers. Standard well construction techniques are discussed in Johnson (1966). The well should be correctly sealed from overlying and underlying units that are not to be directly pumped and so that leakage down the well annulus cannot occur which may interfere with the interpretation of the test. The completed pumping well should be developed by the appropriate methods to remove drilling fluid from the well and to wash and grade the grain sizes of the gravel pack and surrounding aquifer materials. Proper development of the well may prevent an unexpected variation in the pumping rate during the constant discharge test which, if the variation occurred, could lead to inconsistent drawdown data from the pumping well.

8.2.4 Observation Well Siting

The location and number of observation wells depends on several factors:

- o Whether the aquifer tested is confined or unconfined
- o The thickness of the aquifer
- o The anisotropy of the aquifer
- o Location of the screened interval of the pumping well relative to the total aquifer thickness

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- o Location of aquifer boundaries, whether positive (lake or stream) or negative (impermeable boundaries)
- o Practical and economic considerations

Any number of observation wells may be considered. Often, four wells are desirable, three on a line passing through the center of the pumped well and one on a line normal to that line and also passing through the pumping well. A number of guidelines for location of observation wells are presented in the Ground Water Manual prepared by the U. S. Department of Interior and Kruseman and DeRidder (1976).

As a general rule for tests performed in both confined and unconfined aquifers, the observation wells should be screened or completed in a substantial portion of the aquifer thickness in approximately the median depth of the test zone. In some cases, special tests require that observation wells be selectively completed in several depth zones in order to accurately determine aquifer characteristics such as anisotropy and vertical hydraulic conductivity.

The location of the observation well from the pumping well is in part controlled by the aquifer conditions: whether they are confined or unconfined. The location of observation wells generally depends on four aquifer conditions:

- o Most aquifers with fully penetrating pumping wells: observation wells should be located at a distance estimated by using the Theis formulation (Theis, 1935). Use of this formulation is described by Walton (1970). Assumed aquifer parameters are used to determine a location which will give the amount of drawdown required for proper analysis.
- o Thin aquifers with fully penetrating wells: for confined aquifers the nearest observation well should be located at least 25 feet from the pumping well. For unconfined aquifers, observation wells should generally be located 15 to 100 feet from the pumping well.
- o Thick, isotropic aquifers with a partially penetrating pumping well: observation wells should be located one and one-half to two times the aquifer thickness from the pumping well.
- o Thick anisotropic aquifers with partially penetrating well: observation wells should be located at a minimum distance from the pumping well equal to twice the thickness of the aquifer times the square root of the ratio of the horizontal to the vertical hydraulic conductivity.

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8.2.5 Procedures

The field procedures to conduct pumping tests are similar. The basic procedure consists of monitoring the water level over time in the pumping well and each observation well as the pumping well is discharged at a constant rate.

The following data must be recorded accurately at the time the test is performed:

- o Well identification number or location of pumping well and each observation well
- o Location and elevation of each well
- o Location and elevation of reference point from which water depth measurements are made and elevation of ground with respect to the reference point
- o Date and time of test
- o Well depth, pump depth, screen length, well radius and radius of gravel pack plus well screen for each well

All gauges, transducers, flow meters, etc. used in conducting pumping tests should be calibrated before use at the site. Copies of the documentation of instrumentation calibration should be obtained by the WCC hydrogeologist and later filed with the test data records. The calibration records will consist of laboratory measurements and, if performed, any on-site zero adjustment and/or calibration. In cases where a weir or an orifice is used to measure flow rates, the device will be checked on site using a container of measured volume and stopwatch. Accuracy of the meters must be verified before testing proceeds.

If funds are available, it is normally advised to monitor pre-test water levels at the test site for about one week prior to performance of the test. This can be accomplished by using a continuous-recording device such as a Stevens Recorder. This information allows the determination of the barometric efficiency of the aquifer when barometric records are available. It also helps determine if the aquifer is experiencing an increase or decrease in head with time due to recharge or pumping in the nearby area. Changes in barometric pressure are recorded during the test (preferably with an on-site barograph) in order to correct water levels for any possible fluctuations which may occur due to changing atmospheric conditions. Pre-test water level trends are projected for the duration of the test. These trends and/or barometric changes are used to "correct" water levels during the test so that they are representative of the hydraulic response of the aquifer due to pumping of the test well.

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During an aquifer test, water levels should be measured to give at least ten observations of drawdown within each log cycle of time. During the early part of the test, sufficient personnel should be available to have at least one person at each observation well and at the pumping well. After the first two hours, two people are usually sufficient to continue the test. It is not necessary that readings at the wells be taken simultaneously. It is very important that depth to water readings be measured accurately and readings recorded at the exact time measured. A typical aquifer pump test data form is shown as Figure 8-2.

The duration of the test is determined by the needs of the project and the aquifer properties. One simple test for determining adequacy of data is when the log-time versus drawdown for the most distant observation well begins to plot as a straight line on the semi-log graph paper. There are several exceptions to this simple rule of thumb; therefore, it should be considered a minimum criteria. Different hydrogeologic conditions can produce straight line trends on log-time versus drawdown plots. In general, longer tests produce more definitive results. If budget permits, a duration of one to several days is desirable, followed by a similar period of monitoring the recovery of the water level. Unconfined aquifers and partially penetrating wells may have shorter test durations. A knowledge of the local hydrogeology combined with a clear understanding of the overall objectives of the project are very useful in interpreting just how long the test should be conducted. There is no need to continue the test if the water level becomes constant with time. This normally indicates that a hydrogeologic source has been intercepted and that additional useful information will not be collected by continuing the pumping portion of the test.

Measurement of recovering water levels after pumping is concluded is often done to verify results obtained from the pumping portion of the test. The recovering water levels in the pumping well and the observation wells are measured for a period immediately following cessation of pumping. Monitoring of the recovery period should, by rule of thumb, be at least one-half the length of the pumping portion of the aquifer test. This length of time usually allows the collection of useful data for additional analysis.

8.2.6 Data Analysis

Numerous techniques of analysis have been developed by researchers to evaluate water level data collected from constant discharge aquifer pumping tests. Many of the analyses use the graphical "curve matching" technique which involves the matching of theoretical "type" curves to plots of log-drawdown versus log-time from the observation wells. Other analyses rely on other graphical techniques such as application of a straight line to plots of drawdown versus log-time.

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Theis (1935) developed a theoretical formulation which related the lowering of the potentiometric level in an aquifer due to the constant withdrawal of water from the aquifer. This classic formulation has been widely used to predict water level response in aquifers due to specified pumping stresses. Several authors have described the use of this formulation in estimating transmissivity and storativity from aquifer test data: Lohman (1970), Walton (1970), Todd (1981), and Freeze and Cherry (1979). In brief, the method involves superimposing the Theis solution (or "type" curve) on a log-log plot of drawdown versus time data from a test well. The coordinate axis of the type curve must be kept parallel to the field data plot axis. Data from the "match point" is used to solve two algebraic equations which give the value of transmissivity (T) and storativity (S) (or storage coefficient). Hydraulic conductivity (K) may be computed by dividing T by the aquifer thickness (b). An example of the application of this technique is presented in Appendix 8-3.

The same aquifer parameters can also be determined from a semi-log plot of drawdown versus time for either the pump well or observation wells. Cooper and Jacob (1946) showed that after a relatively short time after pumping begins an analysis of the data, plotted as described above, provided essentially the same T, S, and K values as the Theis technique.

Hydrogeologic judgment should be used in applying straight (Cooper-Jacob method) fits to these plots because different hydrogeologic conditions can produce similar trends in the data plot. For example, bounded aquifers produce straight line trends that may yield apparent transmissivity values that are too low. Knowledge of the hydrogeology of the area and the type of aquifer conditions is essential for correct analysis of test data.

Since the development of the Theis equation, several other formulations have been published which attempt to describe the response of certain aquifers to a constant pumping stress. Hantush (1955, 1956) developed formulations and a corresponding set of type curves for an aquifer which is overlain and/or underlain by a confining bed which has significant storage and experiences vertical flow when the adjacent aquifer is pumped. The same curve matching procedure is used here as with the Theis type curve except that several type curves are available for matching to the data depending on the degree of leakage into the pumped aquifer. Hydraulic parameters of the confining unit can be calculated using the set of Hantush type curves.

Another commonly used set of "type" curves was developed by Boulton (1954, 1963) and are used when the aquifer tested is unconfined and may exhibit a phenomenon known as delayed yield. Delayed yield is a result of retardation of drainage due to such forces as capillary tension. Boulton's type curves include a set of early-time type curves and late-time type curves. The early-time data and late-time data are respectively matched to the early-time and late-time type curves to give values for transmissivity, storage coefficient, and specific yield. The particular curve used in the

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set of "type" curves yields additional information concerning how the unconfined aquifer responds to pumping. Neuman (1972, 1974, 1975) also developed a set of type curves for the response of unconfined aquifers to pumping but used different assumptions concerning the physical processes in effect. In practice, Neuman and Boulton curves have been shown to give similar results.

Other less common analytical techniques have been described in detail by the authors mentioned above. A publication by Kruseman and DeRidder (1976) is one of the most complete works on the analysis and evaluation of pumping test data. Methods described (with practical examples) include treatment of aquifers from confined to unconfined under both non-steady and steady-state pumping conditions. Methods of correcting drawdown data from tests in which partially penetrating wells exist is also discussed by Kruseman and DeRidder (1976). In addition, the analyses of data from aquifers which have a non-ideal shape or are bounded in some fashion by different hydrogeologic units are presented. Techniques for analysis of recovery data collected after the completion of pumping are presented. Analyses for various types of variable discharge rate tests, such as the Aron-Scott method, are also presented in Kruseman and DeRidder (1976).

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* These references (or a portion thereof) are included in Appendix 8-4.

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- o With the moment of volume addition or removal assigned time zero, measure and record the depth to water and the time at each reading. Depths should be measured to the nearest 0.01 foot. The number of depth-time measurements necessary to complete the test are variable. It is critical to make as many measurements as possible in the early part of the test.
- o Continue measuring and recording depth-time measurements until the water level returns to equilibrium conditions or a sufficient number of readings have been made to clearly show a trend on a semi-log plot of time versus depth.

The time required for a slug test to be completed is a function of the volume of the "slug" and the hydraulic conductivity of the formation. The slug volume should be large enough that a sufficient number of water level measurements can be made before the water level returns to equilibrium conditions. The length of the test may range from less than a minute to several hours.

If the well is to be used as a monitoring well, precautions should be taken that the wells are not contaminated by material introduced into the well. If water is added to the monitoring well, it should be from an uncontaminated source and transported in a clean container. Bailers or measuring devices should be cleaned prior to the test. If tests are performed on more than one monitoring well, care must be taken to avoid cross contamination of the wells.

8.1.5 Data Analysis

The analysis of slug test data is based on the modification of well known ground water flow equations (either the Theim equation, the Theis equation, or subsequent modification). Several authors have presented analytical solutions for the analysis of slug test data. Most solutions require a semi-logarithmic plot of the data collected: dimensionless head (logarithmic scale) or residual head (logarithmic scale) versus time (arithmetic scale).

Hvorslev (1951) was one of the first researchers to publish techniques of analysis of either constant or slug (falling head) tests in near-surface saturated soils. His analysis for slug tests involves a semi-logarithmic plot of the falling head (or water level) divided by the initial head against time. Basic algebraic equations are presented for different configurations of the soil relative to the test hole. In general, the permeability is proportional to a "shape factor" and inversely proportional to a "time lag." The "shape factor" is determined from the test well characteristics or dimensions. "Time lag" is determined from the semi-logarithmic plot.

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